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PART 12

A PRACTICAL WORK WRITTEN BY EXPERTS

Adjustment of Exciting Lamp Bracket.

The exciting lamp bracket should be examined to see that this is well "home" and tested for focus by placing a white card opposite the aperture plate after removing the tension pad and switching on the exciting lamp. A clear white image should be produced. So long as you can get a clear image on the card, do not worry about the shape of the filament of the exciting lamp.

The bracket should be adjusted to be as far in as possible without reducing the width of the image.

Make sure that the upper guide roller in the sound unit is functioning and is adjusted correctly. Incorrect adjustment may produce sprocket hole or frame noise and, in the case of variable area recording, may produce "clipping" of the peaks, with resulting bad quality.

The runners of the film tension pad, when in position, should bear flat against the film. There should be no tendency to tilt, as this may allow the film to buckle away from the aperture plate and get out of focus.

Adjusting the Idler Roller.

Make sure that the correct length of $19\frac{1}{3}$ frames, or $14\frac{1}{2}$ inches, is allowed between the light and sound gates; this length to be taken when the intermittent has just ceased to move. A two-sprocket-hole loop should be allowed between the last sprocket of the motion picture projector and the 707 drive, and

Fig. 19.—How the Receiver is Connected to the Horn.

This and the preceding photographs which accompany this article show methods of maintaining the apparatus of the Western Electric Co., Ltd.

FAULTS AND HOW TO REMEDY THEM.

	Symptom.	Meter Indications.	Remedy.
Rep. Sets 1 & 2.	No Sound on Film	Exciting Lamp : Zero. 49 Amplifier : Zero.	Make sure F.D. switch is " home." Replace fuse R1 or R2. Should replaced fuse blow make sure amplifier is not pushed too far inside 700 unit.
	Ditto.	Ex. Lamp O.K. 49 Amp. : Zero.	Replace one or both valves in 49 amplifier.
	Ditto.	Ex. Lamp : Zero. 49 Amp. O.K.	Replace exciting lamp bracket by spare.
41 Amplifier	No Sound, Film or Disc.	Filament Meter : Zero. Plate Meter : Zero.	Try " on-off " switch, if no result try new valve in each position in turn. If still no reading try new fuse in Amp. position on charging panel.
	Ditto.	Filament Meter O.K. Plate Meter : Zero.	If meter in 42 is O.K. switch off 42A amp. and disconnect thick pair of leads off Condenser C11, taking care to connect ends of leads together and insulating same.
42 Amplifier	No Sound, Film or Disc.	Meter : Zero. Filaments dark.	Renew fuse in amp. fuse box. If still no result replace amp. fuse to A.C. dis. box. If still no result try door switch.
	Ditto.	Meter : Zero. Filaments alight.	Switch off amp., disconnect both strapping links across terms. 1 and 2, and 3 and 4 of the fuse block inside amp., renew fuse and switch on. If meter now reading about ⅔ of normal, switch off and strap across 2 and 3, switch on. If O.K. carry on, if not switch off and undo link across 2 and 3 and reconnect 1 and 2, renew fuse and switch on.
46 Amplifier	No Sound, Film or Disc.	M3 reading : Zero. M1 and M2 Zero.	Replace both 239 valves. If still no reading, replace amp. fuse on charging panel.
	Ditto.	M3 reading O.K. (in normal position). M1 and M2 and M3 (when button pressed) reading : Zero.	If filaments of 205's dark :—Replace plug fuse in amp. or amp. fuse box. If still no result, try replacing amp. fuse in A.C. dis. box.
			If filaments of 205's alight :—Check H.T. fuses, following same procedure as in case of 42 amp. when meter zero and filaments alight.
43 Amplifier	No Sound, Film or Disc.	No Meter reading. Filaments dark.	If preceding 42 or 46 amp. O.K., look for defective rec. valve. Renew fuse in amp. fuse box. If still no results try amp. door switch.
	No Sound or defective Sound.	Meter reading hard over.	Switch off, disconnect and insulate end of one lead of C1 condenser. Usually the result of defective valve in amplifying position.
	Flashing over.		Switch off and replace defective valve.
	No Sound or faint Sound.	All meters O.K.	Renew horn fuses on charging panel. If fuses O.K. test.
	Ditto.	Ditto.	In case of small systems employing one 46 type amp. only, switch off mon. rheostat to zero, and test stage horns. If now O.K. replace monitor receiver.

Always have spare fuses in a handy position, so that they are available in case of emergency.

In case of trouble on the M.C.B. when on " reg." try running on " var."

another two-hole loop between the 707 and 711 drives. The idler roller on the film tension carriage should be adjusted to within a maximum of two film thicknesses of the 707. The idler on the 711 drive should not be more than two film thicknesses away from the sprocket and in many cases it may be advisable to adjust it much closer than this.

Important Points to Remember.

Do not forget to keep all idler rollers lubricated, but take care to wipe up all surplus oil. Do not let oil get into the photo electric cell compartment and accumulate under the anode block.

Do not allow the light to escape from the arc lamp and penetrate into the film compartment of the 1-A sound unit through the gap through which the film passes.

Do not allow light to be reflected from the porthole glass on to the front of the photo electric cell compartment. This may produce a hum.

Having laced up, use handwheel on 709 to get film into final position. Do not keep repeatedly switching the motor on and off to move the film a few inches. This practice will result in a short life of the switch.

Do not use footswitch for ordinary stopping and starting. This is intended for emergency use only.

Do not make the very common mistake and think that the equipment is not functioning properly unless you are working all out and trying to blow the roof off. This only results in overloading the amplifiers, producing poor quality, and is liable to damage the receivers.

Replacing a Receiver.

If it is necessary to replace a receiver, before disconnecting, make a note of the colour code of the connections and reconnect new receiver in exactly the same way as the old receiver. Check the colour code with other receivers.

Do not use the body of the receiver to get that last turn. By so doing you may cause a slight displacement of the speech coil. Always use the proper spanner supplied for the purpose.

Tracing Trouble.

It is not possible to give more than a brief summary of procedure to be adopted.

In case of trouble take a quick glance to see that all meters on the main amplifiers are reading normally. Then check up on both machines. Should any of the meters not be reading or not be reading normally, you have a clue to the source of the trouble. On page 538 is given a list of symptoms of trouble and the remedy to be taken under various circumstances. Should any of the recommended procedure produce no result, communicate with your service engineer.

NOTES ON R.C.A. PHOTOPHONE EQUIPMENT

The apparatus which is essential to the presentation of talking pictures in a theatre may be divided into two broad groups: First, the apparatus employed for the projection of the picture on the screen; secondly, the apparatus employed for the reproduction of the sound in the theatre.

The first group includes the picture projectors; the arc lights, or other source of illumination, the screen, and auxiliary apparatus, such as the motor generator to provide the arc lamp supply, etc.

The second group includes the soundheads, synchronous discs, amplifiers, loudspeakers with their attendant apparatus.

For the proper presentation of "talkies" all the apparatus in both groups must perform satisfactorily, not only individually, but in conjunction with each other.

This article deals only with the apparatus included in the second group—namely, the sound reproducing apparatus, which, in a typical R.C.A. Photophone installation, would consist of the following main items:—

Soundheads.

The soundhead is used to translate into electrical signals the photographic record of the sound on the film. It consists of

a box-shaped casting mounted on the projector pedestal and supports the picture projection head above it.

The film, after leaving the picture projection head, passes downwards through an aperture in the top of the soundhead and is pulled through a curved sound gate by the constant speed sprocket situated below. The film is then fed past the lower take-up sprocket into the take-up spool box.

The sprockets are positively driven in company with the mechanism of the picture projection head and a mechanical filter is interposed either between the driving shaft and the constant speed sprocket, or between this sprocket and the sound gate, to obtain absolutely constant film speed through the sound gate, irrespective of any minute variations in the drive, caused by the gear teeth, etc.

The exciter lamp is located at the rear of the soundhead in a holder which allows of almost instantaneous substitution in the event of a lamp failure. The light from the lamp is collected by the optical system and focused by it as a fine slit of light on the film in the sound gate. That part of the light which passes through the film continues forward through a further lens on to the photo electric cell (P.E.C.) carried in an enclosure on the front of the soundhead.

In this front enclosure are located also the P.E.C. transformer and an ammeter and rheostat for adjusting the exciter lamp current.

Projector Drives.

Since constancy of speed is one of the essentials for talking picture reproduction, the projector driving mechanism and driving motors are considered as part of the sound reproducing equipment.

When working from a D.C. supply, a special type of automatic speed regulating motor is used, mounted on the projector pedestal, and the drive is transmitted to the main drive of the projector and soundhead by means of a silent chain or multiple belt.

Where A.C. supply is used, constant speed single-phase motors are employed. They are either mounted in a similar position to that used for the D.C. motor, or, alternatively, supported from the soundhead and directly coupled to it by gearing.

Synchronous Disc Equipment.

This apparatus is used for the reproduction of sound on disc recordings.

It consists of a heavy turntable provided with suitable mounting and driven at $33\frac{1}{3}$ r.p.m. by the motor which also drives the projector, the drive being effected either by silent chain or flexible shaft.

A mechanical filter is interposed in the drive to obtain absolutely constant turntable speed.

An electro-magnetic pick-up is carried by a suitable tone arm located adjacent to the turntable and the electrical output is fed through suitable circuits to the " film-disc " switch on the soundhead.

This switch allows the amplifier input to be coupled to either the P.E.C. circuit for sound-on-film reproduction, or to the electro-magnetic pick-up for disc reproduction.

The use of synchronous disc equipment is rapidly diminishing, and many modern installations do not include this apparatus, since sound-on-film recording only is employed with nearly all modern films.

The Amplifier.

The very weak electrical signals received from the P.E.C. or electro-magnetic pick-up require considerable magnification before they can be used to operate the loud-speakers. Four stages of amplification are usually employed, the final stage employing large power valves. Whilst the early types of amplifiers generally employed storage batteries and dry cells for their operation, all modern types of R.C.A. Photophone amplifiers are entirely " mains operated." The various units are carried in a heavy steel frame suitably located in the projection room and all electrical parts are totally enclosed. The front of the amplifier carries the volume control, switches, indicating lamps, etc., and is provided with detachable panels giving access to the valves, etc.

The Faders.

The maximum length of film which can be loaded conveniently on a projector is about 2,000 feet, which is equivalent to about 22 minutes' presentation. Therefore, to enable a continuous show to be presented, a minimum of two projectors must be employed, one machine being loaded whilst the other machine is running.

The function of the fader is to allow either projector to be coupled to the amplifier, the change over from one to the other being accomplished instantaneously and noiselessly.

The usual type of fader consists of a relay type switch situated in the amplifier, controlled by switches situated on each projector.

In the R.C.A. Photophone system, the fader is used solely for the above purpose, and is not used additionally as a volume control, this latter adjustment being accomplished by a separate control on the amplifier itself.

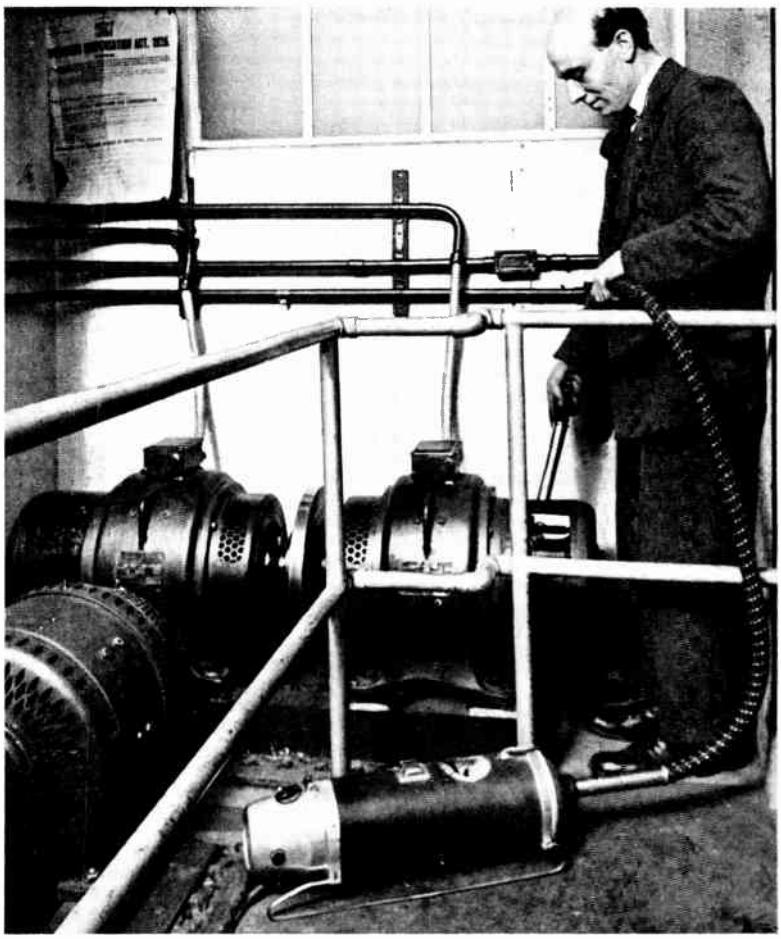


Fig. 20.—Blowing Out the Motor Generator.
A vacuum cleaner which can be reversed provides a convenient supply of compressed air. This and the following photographs which accompany this article illustrate the maintenance of R.C.A. Photophone apparatus

Loud-speakers.

The amplified sound is fed from the amplifier to the loud-speakers mounted on the stage. These are usually located behind the picture screen. They consist of electro-dynamic "moving coil" driving units mounted in directional baffles, which, as their name implies, have the effect of directing the sound to any desired part of the theatre.

The number of speakers employed is determined by the shape and size of the theatre in question, the number and position being adjusted to provide uniform quality and quantity of sound to all parts of the audience.

Other apparatus used in connection with the sound reproduction includes motor generators, which provide suitable

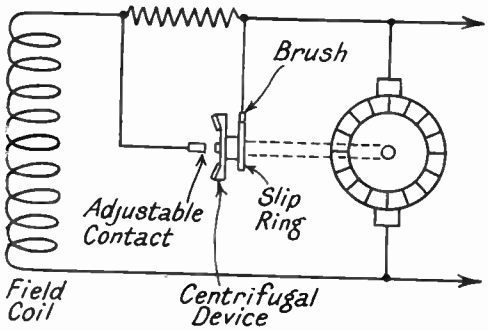


Fig. 21.—D.C. PROJECTOR DRIVING MOTOR (1).
Showing operation of speed control device.

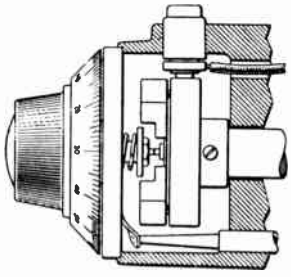
power supply for the operation of the equipment; annunciators and remote volume controls, which enable the volume of sound to be regulated from the auditorium itself. Non-synchronous equipment, which enables standard gramophone records to be played through the amplifier and loud-speakers, etc.

MAINTENANCE AND REPAIR OF R.C.A. APPARATUS.

The aim of these notes is to assist theatre electricians, cinema operators and others with talking picture apparatus under their care, to obtain the most satisfactory operation possible and to indicate the best way of tackling a problem should trouble arise during a show.

It is realised, of course, that the service engineer is available to cope with any trouble that may develop, but pending the arrival of the engineer, the theatre electrician or operator can save delay and loss to the theatre, and gain praise from his manager, if his knowledge of the apparatus enables him to rectify the trouble, if only temporarily, thus enabling the show to proceed.

An R.C.A. Photophone equipment consists of a "soundhead" for each projector, a driving motor for each projector, an amplifier, control panels, loudspeakers, etc. Synchronous disc equipment is supplied with many installations and additional equipment may consist of non-synchronous disc turntables, remote volume controls, etc.



MOTOR UP TO FULL SPEED ACTION OF FLY WEIGHTS BRINGS THE MOVING CONTACT AGAINST THE ADJUSTABLE CONTACT

Fig. 22.—D.C. PROJECTOR DRIVING MOTOR (2).
Showing automatic speed-control device.

Power Supply.

Since R.C.A. Photophone apparatus is designed to operate from 110 volts 50 cycles A.C. or 110 volts D.C. electricity supply, conversion apparatus is usually necessary to transform the theatre supply to either of the above.

Types of Conversion Apparatus.

Three main types of conversion apparatus are used:—motor generators, rotary convertors, transformers. The type used in any one theatre depends on the nature of the supply to the theatre and the type of equipment installed.

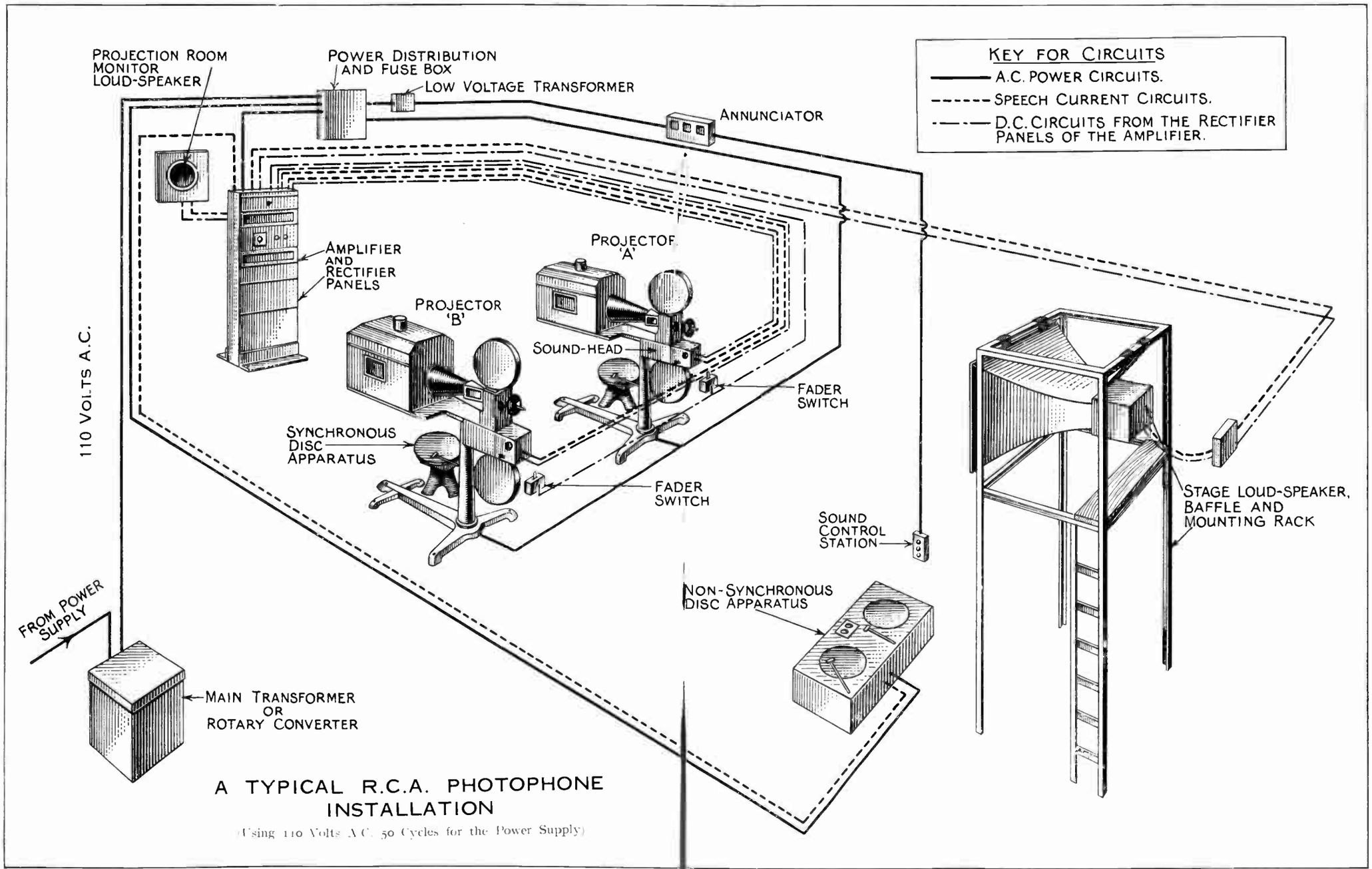
Using a Motor Generator.

This consists of a 4 k.w. motor, wound for the theatre supply, directly coupled to a 110-volt D.C. generator, the two machines being rigidly mounted on a steel base plate.

The generator is a special compound type machine to take care of the load fluctuations during a "change-over," so that the starting of the incoming projector motor does not in any way disturb the speed of the outgoing machine.

Importance of Correct Voltage for Generators.

The correct generator voltage is 110-115 and care should be taken that this voltage is kept correct—by means of the field regulator provided—for, if the generator is operated outside these limits, the compounding may be affected, resulting in "wows," i.e.,—changes in pitch of the reproduction, during a change-over. Incorrect voltage will also upset the operation of projector motors and other apparatus coupled to the generator.



A TYPICAL R.C.A. PHOTOPHONE INSTALLATION

(Using 110 Volts A.C. 50 Cycles for the Power Supply)

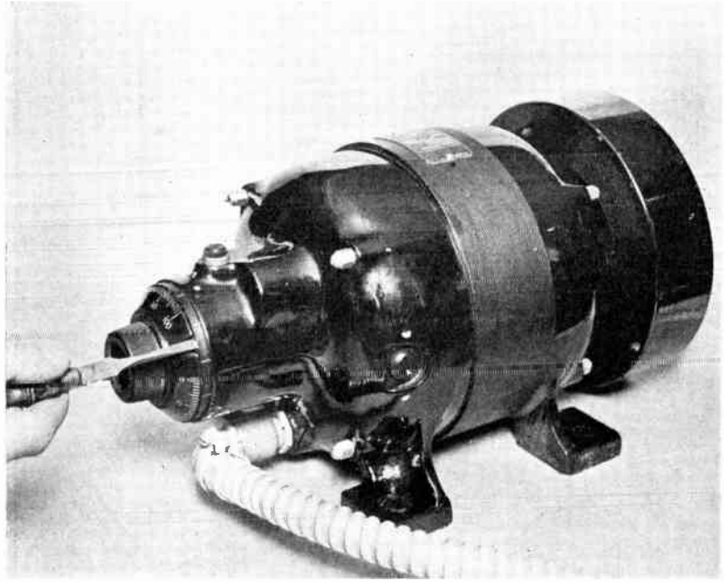


Fig. 24.—Dismantling the D.C. Type Projector Motor.
The first step to take in dismantling the speed regulator is to remove the three screws which hold the dial in position.

Transformer for Conversion Purposes.

This is usually a totally enclosed ironclad instrument with its primary, either single or 3-phase wound, to suit the theatre supply. The secondary winding gives 110 volts A.C. at the terminals and is provided with taps at + 2½% and — 2½% allowing the secondary voltage to be adjusted within these limits.

Although a 3-phase transformer is used in some cases, the standard single phase projector motor is used, the usual wiring being such that the amplifier is connected across one phase and a projector motor across each of the other two phases.

As the transformer is completely enclosed it requires practically no attention and an inspection once every six months should be sufficient.

Small Rotary Convertors.

On equipment utilising 110 volts D.C., small rotary convertors of ¾ K.v.a. or 1½ K.v.a. are used to provide a 110-volt A.C. supply necessary for the operation of the power amplifier, the size of machine used depending on the size of power amplifier.

When to Oil the Bearings.

The ¾ K.v.a convertor is a small double wound machine and is started direct from the 110-volt D.C. supply by means of a double pole switch fuse. The bearings are waste packed and oiling should be carried out once per week by removing the oil covers at each end of the machine.

A More Powerful Convertor.

The 1½ K.v.a. convertor is also a double wound machine. Due to its greater starting current a small "line starter" is used. This unit consists of a double pole line switch, a resistor in series with the motor armature, and a contactor which shorts-out the resistor after the motor has almost reached normal speed. The convertor is provided with oil ring bearings and the level of the oil should be checked every week.

Some Faults and Causes.

On either size convertor, the commutator, slip-rings and brushes should be inspected every week, and particular care should be taken to prevent any copper or carbon dust collecting either between the slip-rings or brush-holders or between these parts and the frame of the machine. Neglect of this point may result in a short circuit and "burn out." Should this occur and a spare machine is not available, the defective machine

Normally, when once set, the field regulator need not be moved again, but should trouble be experienced, the voltage may be checked with a reliable voltmeter across the bus-bars of the distribution box —usually located in the projection room.

How to Reset Brushes in Right Position.

When cleaning the commutator, fitting new brushes, etc., care should be taken not to shift the brush gear assembly, as the correct compounding of the generator depends on the correct positioning of the brushes. However, should it be necessary to dismantle these parts at any time, the brushes can be reset in approximately the right position by lining up a white line found on the brush gear yoke with a similar line on the inside of the end shield at the back of the yoke.

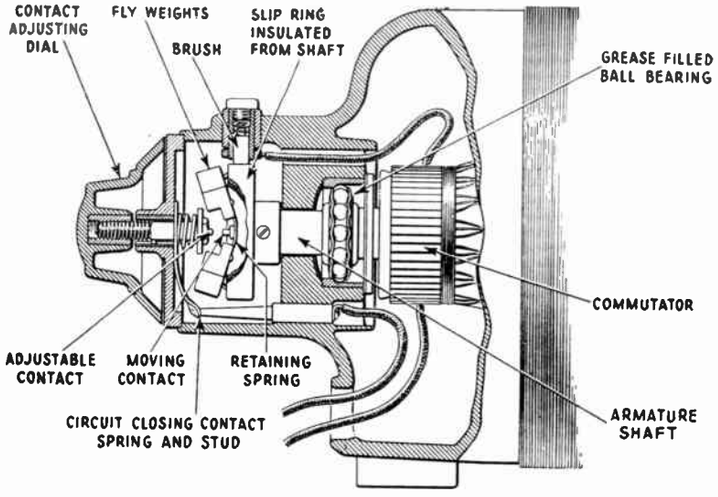


Fig. 23.—D.C. Projector Driving Motor (3).
Showing automatic speed-control device.

Rotary Convertor.

This is a compound type machine with a double wound armature running from the D.C. theatre supply and delivers 110-volt A.C. 50 cycles, single phase. As with the 4 Kw. motor generator special compounding is employed to prevent wows during change-overs. Since the frequency of the supply depends on the speed of the armature, a regulator is fitted in the field circuit in order that the speed may be adjusted.

How to Reset the Speed.

The correct speed is 1,500 r.p.m. and is set at the time of installation. If it is ever necessary to reset the speed, a frequency meter or revolution counter should be employed. The brush position at the D.C. end of the convertor should not be altered in any way, and before any major overhaul necessitating the removal of the brush gear, it should be carefully marked so that it may be reset in its original position.

On both the 4 Kw. motor generator and 4 K.v.a. rotary convertor the brushes should be inspected every week and the commutator cleaned with very fine (00) sand-paper if necessary.

Blowing Out the Machines.

The machines should be blown out with bellows or compressed air once a month. In this connection certain makes of vacuum cleaners which can be arranged to blow instead of suck are useful, and are often found in theatres for ordinary cleaning purposes.

All switchgear, including overload relays, push buttons, etc., should be examined, cleaned and checked for operation every three months. Bearings should be cleaned and repacked with grease every year.

should be carefully inspected and cleaned at the points mentioned. It may be found that the fuses burn out soon enough to prevent damage to the windings and with the fault located and cleared, the machine may be put back into service.

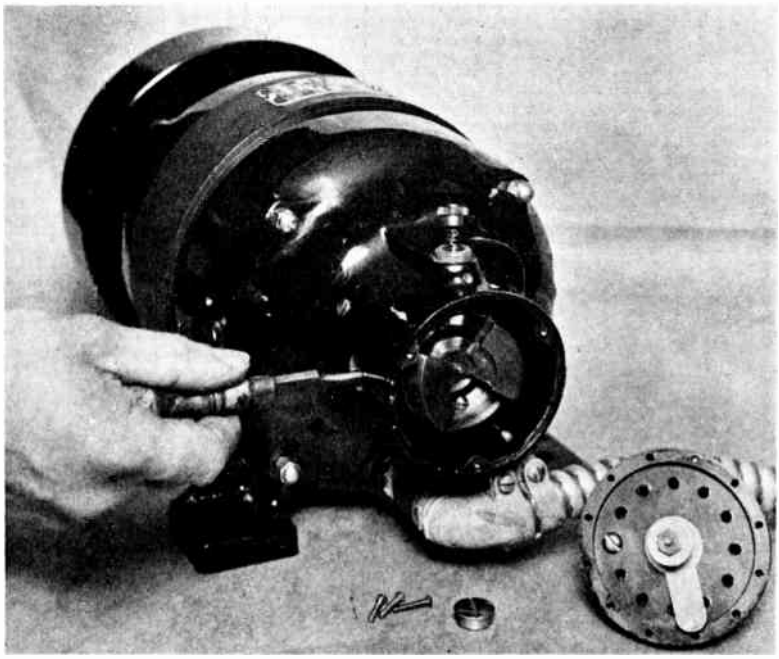


Fig. 25—Dismantling the D.C. Type Projector Motor. Second Step. Slackening the grub screw which locks the rotary mechanism to the shaft.

Using Two Convertors.

On a number of installations two convertors are used, one machine being a "stand-by" for emergency service only. In such cases a four-pole double-throw switch is used to transfer the power supply from one convertor to the other.

Don't Use Two Machines Alternately.

It is common practice to run these two machines on alternate days or weeks. This should *not* be done. One machine should be kept definitely for emergency use only, its operation being checked by using it one or two days only per month. Thus when the regular machine requires overhaul the spare machine is in good condition and is not likely to give trouble pending the return of the regular convertor.

A Three Unit Motor Generator Set.

This set used with type PG-13 (G) equipment consists of three machines in line on a common bed plate and is used to provide the necessary H.T. and L.T. D.C. supply for the operation of the amplifier and associated equipment.

The driving motor of approximately 1 h.p. may be either 110 volts D.C. or 110 volts A.C. single phase, according to the type of conversion apparatus employed. The motor is directly coupled to a 12-volt generator, which in turn is coupled to a 600-volt generator. The fields of both generators are excited by the 600-volt machine, but rheostats and voltmeters are provided for the individual adjustment of the two machines. To replace fuses it is necessary to remove a cover plate by unscrewing the knurled nut at the top of the control panel; the removal of this plate operates a safety switch which automatically disconnects the + 600 line from the generator.

All the bearings are waste packed and should be kept well saturated with medium machine oil.

Cleaning the Commutator.

It is most important that the commutators be kept absolutely clean and the brushes well bedded down. Inattention

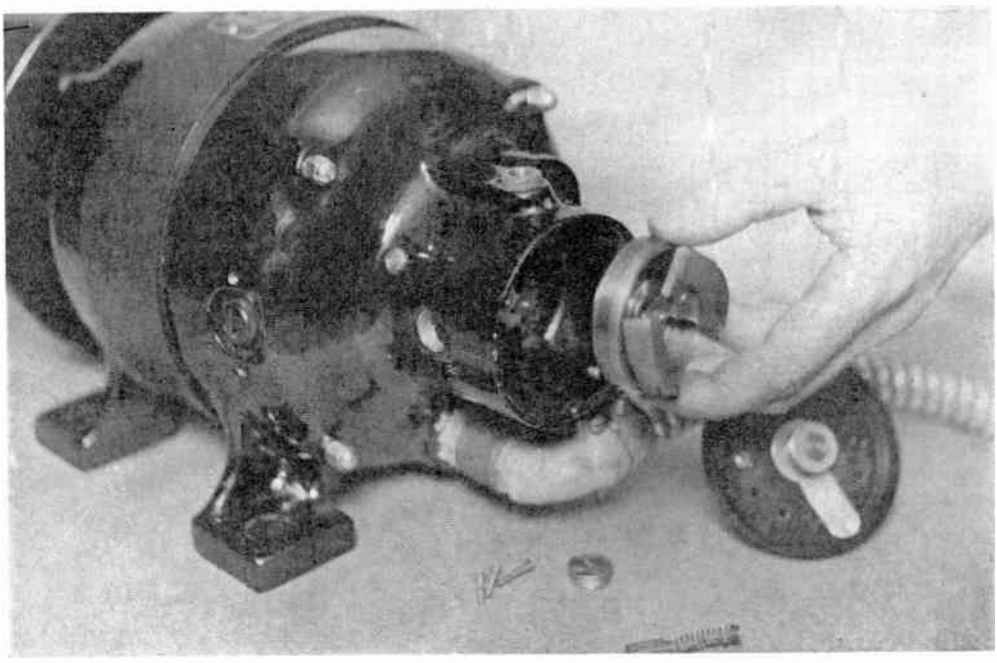


Fig. 26.—DISMANTLING THE D.C. TYPE PROJECTOR MOTOR. THIRD STEP.
How to remove the rotary mechanism from the shaft.

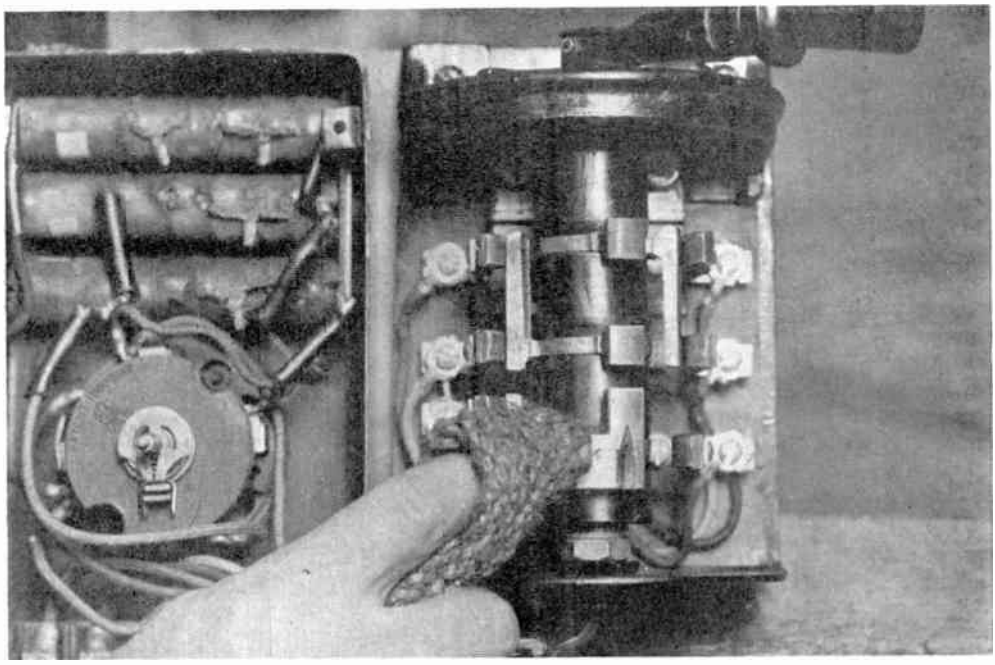


Fig. 27.—CLEANING THE CONTACTS OF THE STARTING SWITCH OF THE D.C. TYPE PROJECTOR MOTOR.
These should be cleaned monthly and lightly coated with vaseline to prevent wear.

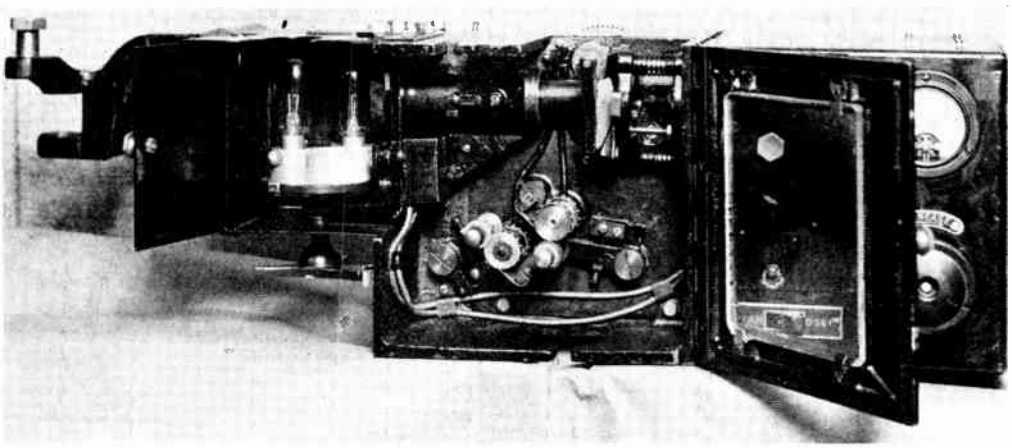


Fig. 28.—TYPE PS-8 SOUNDHEAD.

to these points will lead to noticeable generator hum in the loud-speakers. The 12-volt generator commutator may be reached through a hole in the lower portion of the end shield. Use only "00" sandpaper and clean rag. Do not attempt to clean either of the commutators while the machines are running. When new brushes are required they should be very carefully bedded down with sandpaper wrapped round the commutator, care being taken that the sandpaper is passed under the brushes in the direction of normal rotation of the armature.

Care taken with these points will be amply repaid by freedom from hum or other commutator trouble.

PROJECTOR DRIVE MOTORS.

D.C. Type.

This is a 110-volt shunt wound motor with a special type centrifugal regulator carried in an extension of the end shield outside the bearing at the commutator end (See Fig 22). The operation of the device may be understood from Fig. 21. As the motor speeds up, the fly weights move out and bring the revolving contact closer to the stationary contact. When the motor reaches a certain speed these contacts touch and the resistance in the field circuit is short circuited. This allows the field current to increase and the motor slows down with the result that the contacts open again, the resistance is again in circuit and the motor speed increases. This continues, the switch opening and closing very rapidly and the motor rotates at a practically constant speed. If the dial is rotated the distance between the contacts is altered and hence the speed of the motor changes.

The periodic inspection of these parts should be left to the service engineer, but should trouble be experienced during the show the apparatus can be dismantled fairly easily.

Some Causes of Trouble.

The usual indications of trouble are repeated "wowing," or a sudden drop in speed, and inability to regain speed by adjustment of the dial. First remove the dial. This is done by removing three screws which are accessible by rotating the dial so that the notch uncovers the three screw heads in turn. Examine the exposed mechanism carefully and if everything appears to be satisfactory, clean the contacts, and the slip-ring, and reassemble. If, however, the spring holding the flyweights has broken it will be necessary to remove the rotating parts.

How to Remove Rotating Parts.

First remove the small brush from its holder on top of the housing and open the inspection port at the side by removing

the large nickel-plated screw. Rotate the armature slowly until a grub screw is seen through the port, locating the rotary mechanism on the shaft. Slacken this screw and the complete assembly may be withdrawn.

A Temporary Adjustment of Speed.

The motor may now be run, but the speed will probably be too high for correct projection. If available, a small rheostat —radio type of about 100 ohms will do— may be connected between the slip-ring brush-holder and the long stud at the bottom of the housing, which is normally in contact with the spring connector to the movable contact on the dial.

With this rheostat in place, the speed of the motor may be controlled in a manner similar to that of an ordinary shunt wound machine.

This makeshift will enable the show to proceed, but the proper speed control mechanism should be replaced as soon as possible.

The ordinary motor brushes should be examined once per month and the commutator cleaned if necessary. The contacts of the motor controlling switch should also be examined monthly and if necessary the switch segments should be lightly coated with vaseline to prevent undue wear.

Do not oil the bearings of this motor. They are packed with grease and only require attention yearly.

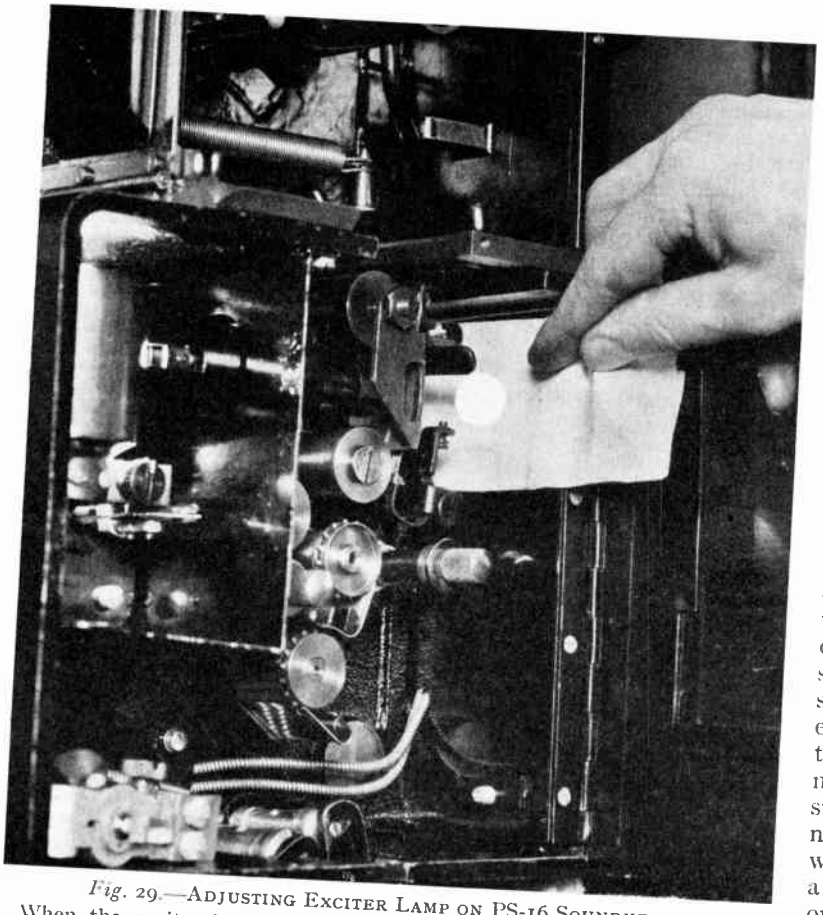


Fig. 29.—ADJUSTING EXCITER LAMP ON PS-16 SOUNDHEAD.
When the exciter lamp is correctly adjusted a circular disc of light is obtained on a piece of paper placed between the sound-gate and photo cell housing.

A.C. Projector Motor.

This motor operates from a 110-volt 50-cycle, single phase supply and is started by means of a split phase winding which is connected in series with a resistance mounted in a box at the end of the motor. The supply is connected to this winding through a centrifugally operated switch situated at the end of the armature.

Starting the Motor.

On starting, this switch is closed and both windings of the motor are used. As the motor comes up to speed the flyweights on the centrifugal device move outwards away from the shaft and in so doing strike a metal pin which operates the switch to disconnect the starting winding. Waste packed bearings are employed and oiling should be carried out once per week.

What to Do When the Motor Will Not Start.

If the motor " hums " but will not start when switched on, a fault may have developed in the centrifugal switch, in which case the projector may be got under way by hand cranking up to speed and then switching on the power. The running winding alone keeps the motor working at its correct speed.

How to Correct " Humming."

Should the motor start satisfactorily but continue to run with considerable " humming," accompanied by severe heating of the resistance box at the end of the motor, it is probable that the centrifugal switch has failed to disconnect the starting winding. Give the projector an additional boost with the hand crank ; the overspeeding may force the switch to act. If this fails, disconnect the starting winding by removing the lead from one end of the starting resistance and then start the motor in the manner described in the previous paragraph.

In either case, the motor should be dismantled and the trouble rectified at the earliest possible moment.

Soundheads.

Sound reproduction from film recordings requires that the variation of the amount of light transmitted through the sound track shall be accurately translated into sound.

How Light is Translated into Sound.

To accomplish this, a thin beam of intense light, the width of which is

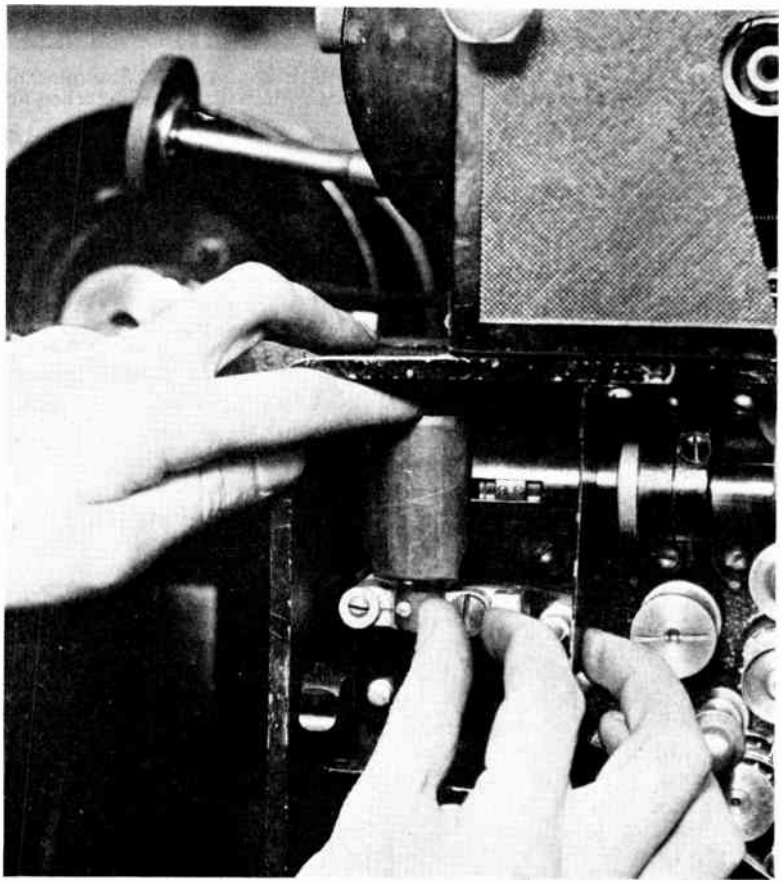


Fig. 30.—ADJUSTING EXCITER LAMP FOR CORRECT POSITION.
The knurled screw between finger and thumb locks the lamp in the desired position.

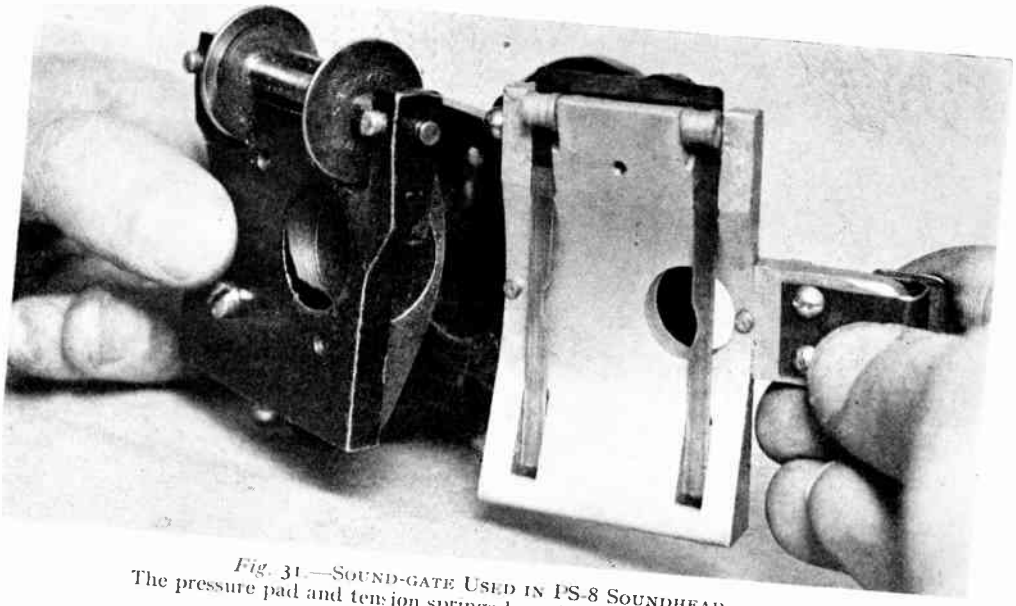


Fig. 31.—Sound-gate Used in PS-8 Soundhead.
The pressure pad and tension springs have been detached for cleaning.

approximately equal to the width of the sound track, is focused on the sound track. The varying light which passes through the film, due to the photographic recording on the track, affects a sensitive photo-electric cell so as to cause a varying current to pass through it. In the R.C.A. Photophone system this varying current is passed through the primary winding of a transformer. The voltage generated in the transformer secondary is amplified and used to operate the loud-speakers.

The two main types of soundheads are illustrated in Figs. 28 and 29. The electrical arrangements of the heads are similar.

Exciter Lamps.

Exciter lamps of 10 volts 5 amps. are used in most equipments and a rheostat and ammeter are provided to enable the lamp current to be correctly adjusted. Never operate above 5 amps. or below $4\frac{1}{2}$ amps. Too high a current will very materially reduce the life of the lamp. Too low a current may result in distortion, due to alteration in the colour of the light; also excessive amplification will be needed, due to the smaller output obtained from the photo-electric cell.

Maintenance of Exciter Lamps.

Exciter lamps must be kept clean and should be replaced, even if not burnt out, as soon as a dark coating becomes apparent inside the lamp. The lamps can be adjusted in their turret for proper positioning. They should be raised or lowered in their socket until a circle of white light is obtained on a card or piece of white paper placed between the sound-gate and the photocell housing. If the position is not correct, the circle will not be complete.

The lamp is clamped in position by means of the knurled nut in the lamp socket. Do not use pliers as the exciter lamp base is easily cracked.

Cleaning the Optical System.

The optical system is a delicate piece of mechanism and its adjustment should always be left to the service engineer. If necessary, however, the front and rear lenses may be lightly cleaned with a piece of lens cleaning tissue or soft silk to remove any oil or dust which may collect.

Types of Soundgates in Use.

Two types of soundgates are in use, Figs. 31 and 32. It is essential that these

parts be kept perfectly clean and free from traces of emulsion off the film and it is advisable to clean the guide and tension springs between each reel. It is sometimes found with the soundgate shown in Fig. 32 that the film has a tendency to run out of the gate, usually at the side farthest from the operator. If this occurs, it is a sign that the tension springs require adjustment.

Adjusting Spring Tension.

The tension of the inside spring, i.e., the one farthest from the operator, should always be slightly tighter than the outside spring. To adjust this tension, slacken the two small tension spring clamping screws and turn the tension adjusting screw in the required direction. Do not forget to tighten the clamping screws after this adjustment.

The photocell enclosure contains the P.E. cell and mounting socket, and in addition, the photocell transformer, "film-disc" switch and terminal rack.

Check, occasionally, the condition of the rubber cushion which supports the P.E. cell transformer, for, should the transformer come in direct contact with any part of the soundhead, considerable noise may be picked up and passed to the loud-speakers.

Care of Photo-electric Cells.

Photo-electric cells are delicate and should be treated with care for their sensitivity is easily destroyed. For example, do not examine the cell in the light from the arc lamp. The cell may still look the same, but it will probably have lost most of its output after such examination, due to the strong light. Spare cells should always be stored in boxes away from light and damp.

Two Types of "Faders."

As each succeeding reel of film comes to an end, it is necessary to transfer the amplifier input from the outgoing projector to the incoming one.

Two types of "faders" are used to accomplish this "change-over" on R.C.A. Photophone equipment.

Potentiometer Type.

The potentiometer type fader is shown diagrammatically in Fig. 35. It will be seen that when the movable arm is in the "off" position the input to the amplifier is short circuited and therefore nothing is heard. If the arm is moved to the left or right, however, the corresponding projector is coupled to the amplifier. This type of fader is mounted on the input control panel and access to the contacts and switch arm is obtained by removing the control knob and name plate.

Relay Type.

The relay type fader is shown in Fig. 36. It will be seen that in this type the input

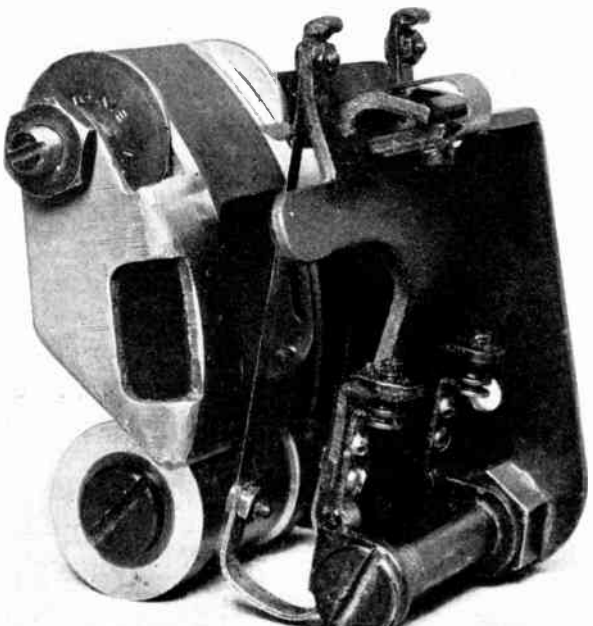


Fig. 32.—SOUNDGATE USED IN PS-10 TYPE SOUNDHEAD.

The gate is shown "open." Note the two tension spring clamping screws, one above the other, which must be slackened before the tension can be adjusted as shown in Fig. 33.

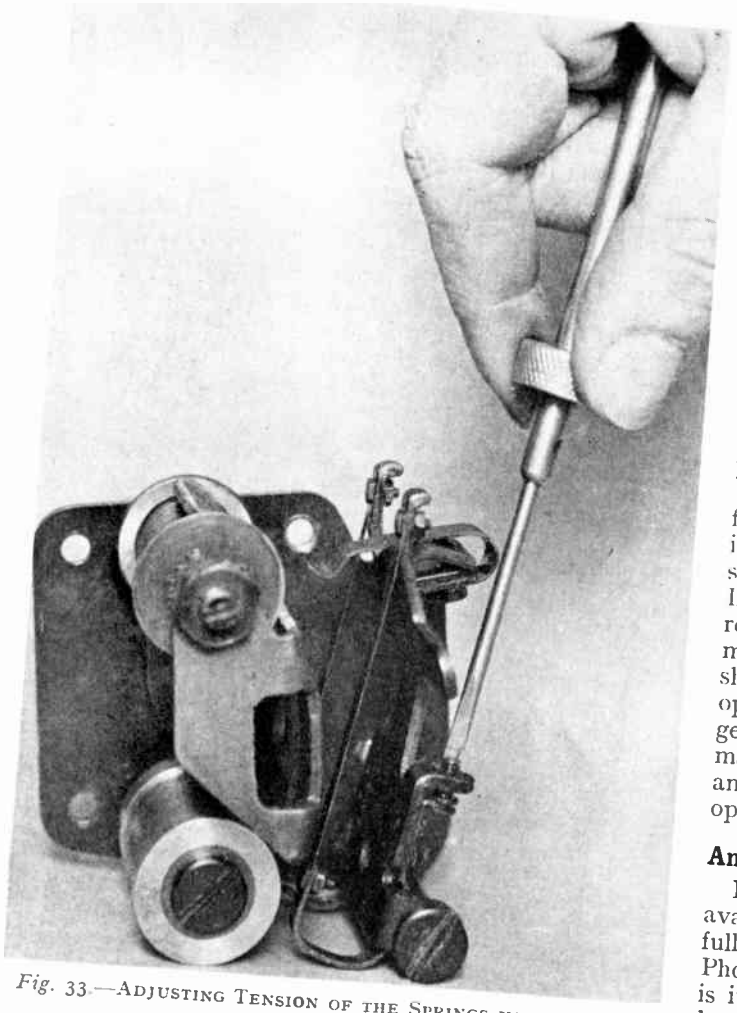


Fig. 33.—Adjusting Tension of the Springs in the Sound-gate.

Under normal conditions the tension of the nearer spring should be slightly less than that of the other. (See also Fig. 32.)

to the amplifier is instantly changed from one projector to the other by means of a relay type switch controlled by two three-way switches, one on each projector.

A second set of contacts transfers the the pilot lamp connections to indicate which projector is in use. On Type PG-30 (H) equipments an additional relay is operated in parallel with the fader relay in order to transfer the exciter lamp supply from one projector to the other.

How to Clean Contacts.

With either type of fader it is absolutely essential that all contacts be kept clean and free from carbon dust, etc., otherwise cross talk or loss of sound may develop.

The fader contacts should be cleaned with a rag moistened with Thawpit, which liquid should also be used for volume control contacts, etc. Do not use oil, vaseline, emery, sandpaper or metal polish.

Should the relay type fader fail to operate, inspect the contacts in the switches on the projectors. If these are O.K. but the relay armature fails to move, the operating coil should be checked for an open circuit. In emergency, the relay armature may be operated by hand and lightly wedged in the operating position.

Amplifiers and their Faults.

It is not possible in the available space to describe fully every type of R.C.A. Photophone amplifier, nor is it advisable for anyone but the service engineer to tamper with the internal wiring, etc. However, a short description of the amplifiers most frequently employed may enable the more usual faults to be diagnosed and possibly rectified.

All R.C.A. Photophone amplifiers consist of two or three stages of voltage amplification coupled to a power stage consisting of one or more units, according to the size of the theatre.

Checking Voltages.

Voltage amplifiers type SPU-63 and SPU-206, used on earlier equipments, con-

sist of three transformer-coupled stages employing two UX-210 or UX-112A Radiotrons in each stage. Filament supply is obtained from 12-volt storage batteries, while plate and bias voltage are supplied by dry cells contained in the battery compartment of the amplifier rack. Voltages should be checked weekly by means of the voltmeter on the front of the rack and the dry cells should be replaced when the indicated voltage has fallen 20 per cent. below normal value. The power amplifier type SPU-62, used in conjunction with either of the above voltage amplifiers, consists of two UX-250 Radiotrons transformer coupled to the voltage amplifier and to the loudspeaker. The unit obtains all its power from the 110 volt A.C. line, two UX-281 Radiotrons being used to provide a rectified supply to the plate at 425 volts. This power amplifier also carries a Rectox metal oxide type rectifier which provides the field current for the loudspeakers.

Care should be taken that no metal object comes in contact with the Rectox unit thereby causing a short circuit which would damage not only the rectifier but also the transformer.

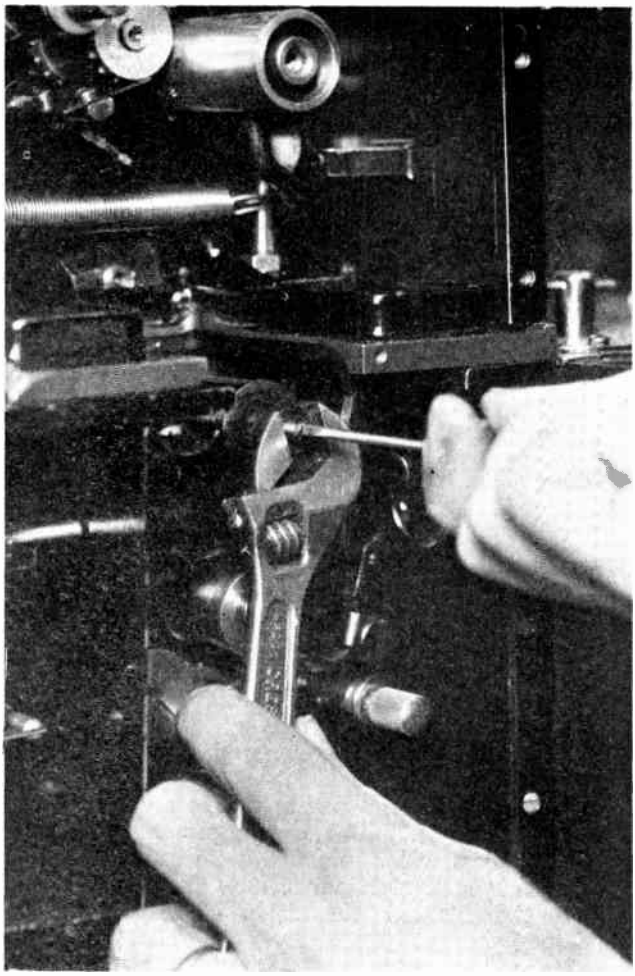


Fig. 34.—Adjusting the Lateral Guide Roller on Type PS-10 Soundhead.

The large nut locks the guide roller shaft, which is held stationary with the aid of a screwdriver.

The voltage and power amplifiers used with the PG-13 (G) equipment are constructed in one unit. Three UX-112A Radiotrons are used to provide three stages of voltage amplification, the final stage being auto-transformer coupled to four UX-250 Radiotrons in the power stage.

Shorting Resistors to Prevent Loss of Sound.

The filament and plate voltages for this amplifier are supplied from the motor generator set described in an earlier paragraph. The small dry cells which provide grid bias should be checked occasionally and replaced if the voltage of the individual three-cell units is below 3.5 volts. It is sometimes found that an intermittent loss of sound occurs when the volume control is in certain positions. Should this occur, the trouble may be temporarily overcome by shorting out with a piece of wire the particular resistor coupled to this stud. To gain access to

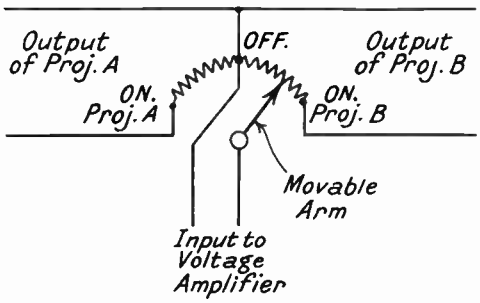


Fig. 35.—Connections of Potentiometer Type Fader.

the resistors the four small screws holding the volume control in its case should be removed and the control gently pulled forward. Particular care must be taken when replacing the unit that no part of the control comes in contact with the metal case. Before carrying out this operation switch off the motor generator and disconnect the bias battery.

On PG-30 (H) equipments both voltage and power amplifiers obtain all necessary power supplies from the 110-volt A.C. supply, indirectly heated type Radiotrons being used in the voltage amplifier and UX-250 Radiotrons in the power stage. Additionally, separate panels are mounted in this amplifier, carrying metal oxide rectifiers which provide a 10-volt supply for the exciter lamps, etc., and a supply suitable for the fields of the loud-speakers.

On PG-28 (J) equipments the voltage and power amplifiers are in one unit. The voltage amplifier is similar to that used in PG-30 equipments, but the power stage consists of two UX-245 Radiotrons.

Testing Valves.

The routine testing of the valves must be left to the service engineer, since special instruments are required, but in case of emergency they may be checked for performance by substituting the spare set of valves, which should always be kept complete.

As valves become old, their "emission" becomes less and eventually becomes so low that distortion and lack of volume is noticed. As soon as the service engineer's tests indicate that this condition is approaching, the spare set of valves should be inserted and fresh valves ordered to replace the spares.

Temporary Means of Stopping Valve Noises.

Sometimes a valve appears unduly microphonic, i.e., causes noise or howls in the loud-speaker, due to mechanical vibration of the valve electrodes. Should it be necessary to continue using such a valve, a quantity of cotton wool or similar material wrapped round the valve may alleviate the trouble. However, it should be replaced by a good valve as soon as possible.

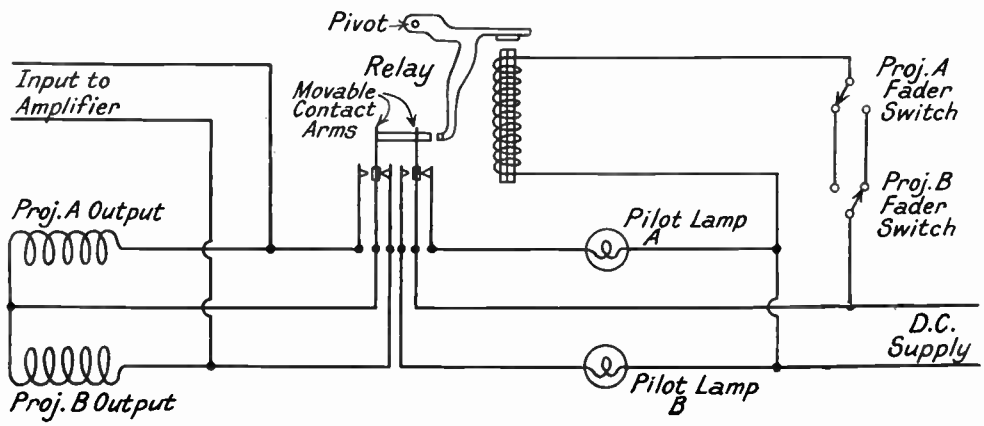


Fig. 36.—Connections for a Relay Type Fader.

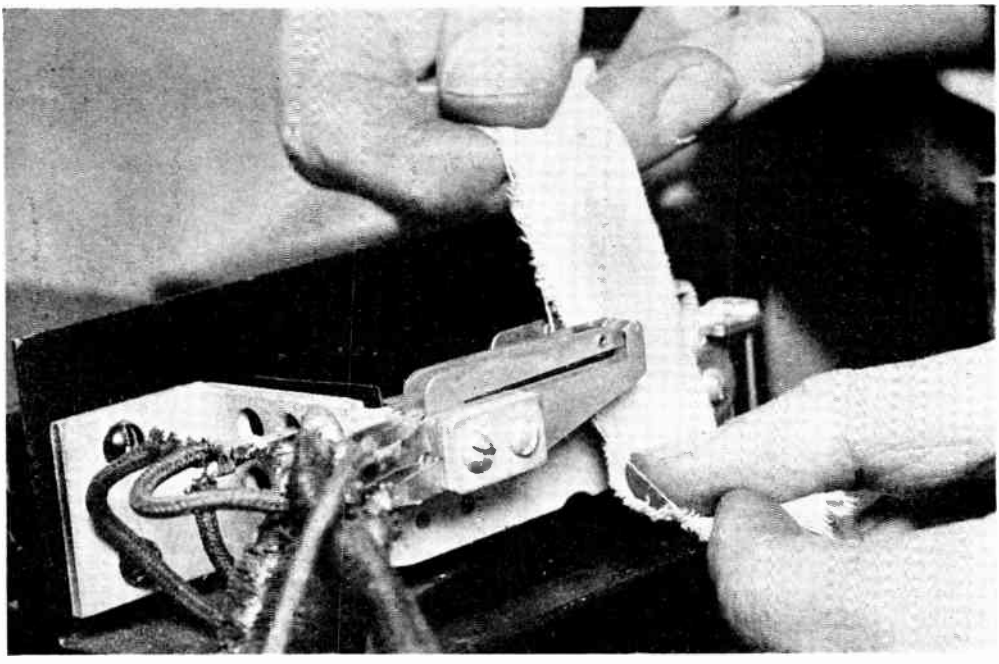


Fig. 37.—CLEANING THE CONTACTS OF A FADER RELAY.
A piece of cloth moistened with Thawpit is gently drawn up and down between the contacts.

What Blue Haze in Valves Means.

If a valve develops a blue haze during operation, inside and outside the plate, "gas" is indicated. Many good valves show a haze which clears away a few minutes after switching on.

If it continues, however, the valve should be changed, since the effect of gas in a valve is to cause distortion and noisy reproduction.

Burnt-Out Valves.

Burnt-out filaments are easily detected by their failure to light. A burnt out valve in a stage employing two or more valves will result in loss of volume and quality; but in an emergency, operation may continue until it is convenient to replace the defective valve. A burnt-out valve in a stage employing one valve only will result in no sound and must be replaced immediately.

Valve sockets and prongs should be cleaned from time to time to avoid noises due to bad contacts.

Do not remove valves when the amplifier is switched "ON." Neglect of this precaution may damage other valves in the circuit.

Power valves and rectifier valves become very hot in operation and will burn the hand. Avoid putting hot valves on cold metal or wet surfaces.

Keep all terminal strips and exposed connections clean and free from carbon dust from the arc lamp.

LOUD-SPEAKER UNITS.

All loud-speaker units used on R.C.A. Photophone equipment are of the electro-dynamic moving-coil type, driving either 8-inch or 6-inch diameter cones.

How the Units are Mounted.

The stage units are mounted on directional baffles suitably arranged behind the screen to give satisfactory distribution of sound throughout the theatre.

The units are practically trouble-free, but should be examined occasionally for the centring of the coil in the air gap of the magnet.

Fig. 38.—REMOVING THE VOLUME CONTROL FROM THE TYPE PG-13 AMPLIFIER.
When the four small screws are withdrawn from the corners, the control may be removed from its case for cleaning or for the temporary repair shown in Fig. 39.

What to Do if a Voice Coil Burns Out.

If a voice coil should burn out during a performance and more than one speaker is employed, disconnect the voice coil connections of the defective speaker and continue on the remaining speakers.

If only one speaker is in use and a spare unit is kept at the theatre, this spare unit should be installed and the defective cone in the old unit replaced when convenient.

Where Two or More Speakers are Used.

Where two or more speakers are installed, it is important that the connections to the field coil or to the voice coil are never reversed after the completion of the installation, as this will result in poor sound in the theatre. If any doubt is felt about this point, the service engineer should be asked to check the phasing of the loud-speakers.

Synchronous Disc Attachment.

This equipment consists of a separate pedestal base carrying a turntable and suitable driving mechanism, which is positively operated by the projector driving motor.

The electro-magnetic pick-up is carried by a balanced tone-arm, which rotates in a bracket bolted to the pedestal base.

The pick-up is of the low impedance type and consists of a permanent magnet, a soft-iron armature and a small coil of wire. The armature which carries the needle is pivoted in rubber and its upper end is held in place by small rubber damping blocks.

Adjustment of Pick-up.

The pick-up fits into a socket at the end of the tone-arm and is clamped in position by a small screw carried by the pick-up. The electrical connections are completed automatically when the pick-up is inserted into the socket. The correct pressure on the needle point is 6 ounces and can be adjusted by altering the position of the balance weight carried at the extreme end of the tone-arm behind the pivot.

The tone-arm vertical pivot rests on a ball bearing inside a brass bushing in the tone-arm bracket. Should this ball bearing be lost, the tone-arm may bind, causing the pick-up needle to jump the record grooves. A drop of oil should be applied to this pivot once a month.

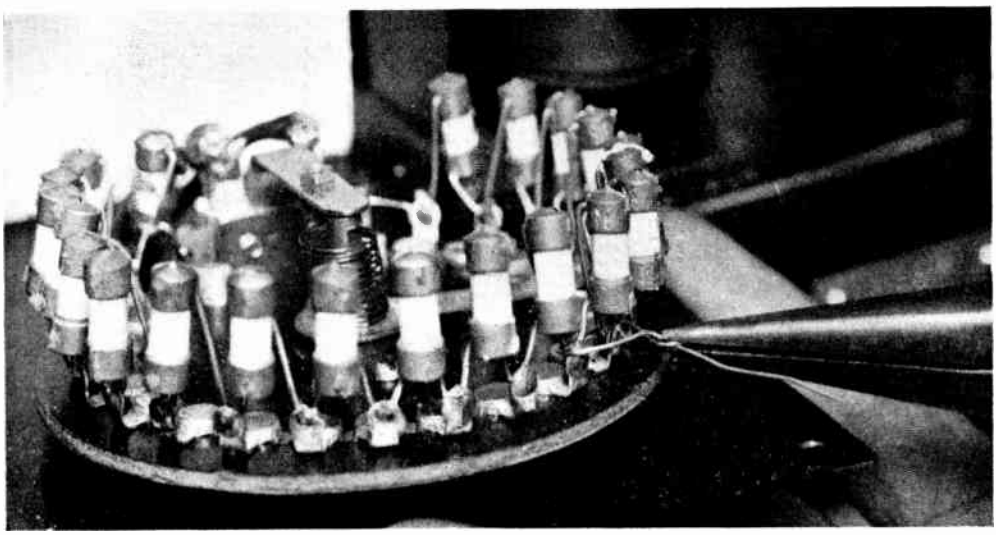


Fig. 39.—EFFECTING A TEMPORARY REPAIR TO A VOLUME CONTROL.
This is done by shorting out a defective resistor.

A Cause of Mechanical Noise.

The horizontal pivot is carried in sponge rubber cushion and felt washers, to prevent mechanical vibrations affecting the sound produced by the pick-up. Should these cushions become displaced so that the metal of the tone-arm touches the pivot or support, considerable mechanical noise will be produced in the loud-speakers.

The output from the pick-up is fed *via* a shielded cable to the " film disc " switch on the soundhead or control box.

Trouble During Operation.

No matter how well a talking picture equipment may be designed, the comparatively complicated apparatus may develop trouble during operation. Such trouble, however, can be reduced to a minimum, if not entirely eliminated, if the equipment is properly taken care of and checked over frequently and thoroughly.

Cleanliness is of prime importance. Dirty equipment is responsible for a very large percentage of cases of distortion, loss of volume, noisy reproduction or " no sound."

Even with the best of care, however, trouble may develop occasionally which requires immediate correction and it is important that these emergencies be met with a definite plan of action.

Points to Watch For.

Probably the most common of the troubles experienced are those which are due to " slip-ups " in operation, for example : Switches or rheostats in the wrong position, sound gate left open, non-synchronous plug left in position when it should be withdrawn, etc.

After making certain that the trouble is not due to a " slip-up," the part of the equipment causing the trouble should be found by systematic tests and the trouble remedied. Usually the most effective method of locating a defective part is to determine to what extent the equipment is still operative.

What to do When no Sound is Obtained.

For example : If no sound is obtained from sound on film when starting or changing from one projector to another, the first thing to be done, after checking for a " slip-up, " is to find out if sound can be obtained from the disc circuit. Put the " film disc " switch to " disc " position and stroke the needle of the pick-up. If sound is heard, the indication

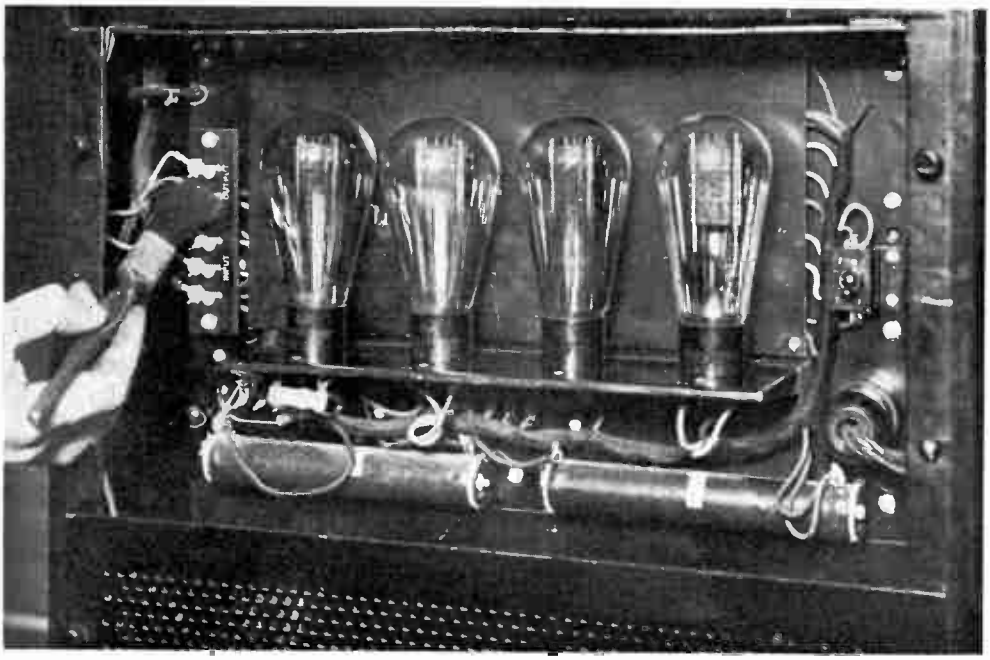


Fig. 40.—CLEANING THE TERMINAL RACKS OF TYPE PG-30 POWER AMPLIFIER.
A stiff brush is useful for cleaning terminal racks.

Fig. 41.—CORRECT METHOD OF REMOVING A VALVE.
Do not remove a valve by gripping the glass, as this may loosen the base and break the internal connections.

is that all the equipment, except the photocell circuit, is O.K. If no sound is obtained from either pick-up or photocell, try the other projector. If sound can be heard from one projector and not the other, the indication is that the defect is in the fader or possibly film disc switch, since it is not probable that both pick-up and photocell would fail at the same time.

Trouble With Amplifiers.

If sound cannot be obtained from either projector, the trouble probably lies in the amplifier. The voltage amplifier can be checked by switching over to the stand-by amplifier, if one is available, or if a non-synchronous gramophone is available, the amplifier can be checked by plugging in the gramophone into the jack provided and listening for sound whilst stroking the needle of the gramophone pick-up. If sound is obtained from the gramophone and not from the projectors, the amplifier is O.K., and the trouble lies in the fader or wiring to the sound-heads.

If sound is not obtained from the gramophone, the indication is that the trouble is in one of the amplifiers. If only one voltage amplifier and one power amplifier are used, no simple test can be made to isolate the defect to one of them, and it is necessary to check over both units for defects.

When Two Amplifiers are Used.

If two power amplifiers are used, it is reasonable to assume that both of them will not develop a defect at the same time. Therefore, if no sound can be obtained from either power amplifier, the indication is that the defect is in the voltage amplifier.

Checking for Continuity.

If no sound is obtained at the stage loud-speakers and sound is O.K. at the monitor in the projection room, the trouble must be somewhere in the line from the amplifier to the stage units.

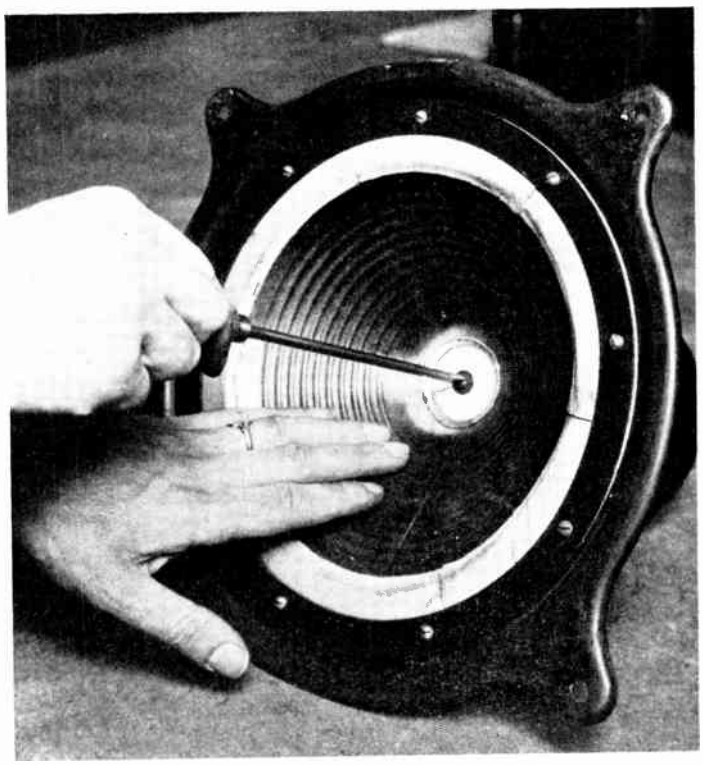


Fig. 42.—Adjusting the Centring of the Voice Coil in the Air Gap of a Stage Loud-speaker Unit.

Possibly the stage plugs, if used, have not been inserted, or only partially inserted, resulting in an open circuit on one or more lines. Check for continuity of the field circuit by removing each of the field plugs one at a time. If a small arc is formed at the moment of breaking contact, the field supply is O.K. Alternately, the leads of a 110-volt 25-watt lamp or voltmeter may be inserted in the field plug.

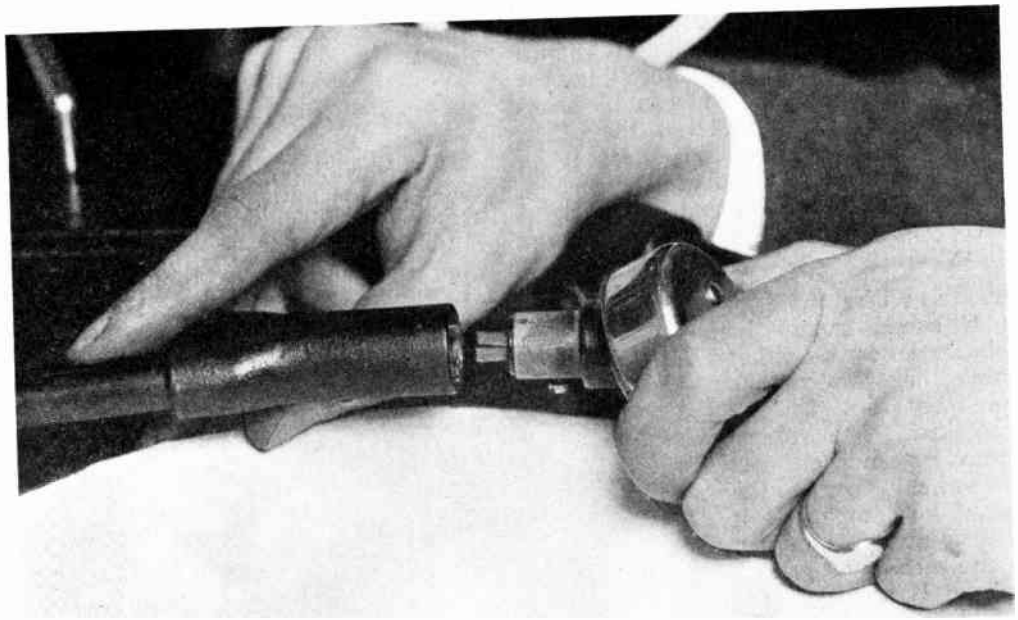


Fig. 43.—INSERTING THE PICK-UP INTO THE TONE-ARM.

The two flat spring contacts complete the electrical connections and the screw underneath clamps the pick-up in position.

Checking Voice-Coil Continuity.

The voice-coil continuity may be checked at each speaker by using a pair of headphones across the incoming voice-coil leads.

If when using sound on disc, sound can be obtained from one pick-up and not from the other, it is probable that the pick-up itself has become defective, and it will be necessary to substitute the spare pick-up. When removing a pick-up loosen, *but do not remove*, the set screw which holds it to the tone-arm and pull the pick-up straight out.

Look for Burnt-Out Exciter Lamps.

No sound when using sound on film may be due to a burnt-out exciter lamp, sound gate aperture completely clogged or a defective photocell. If unequal volume is obtained from the two projectors and the exciter lamps are correctly focused and drawing their correct current, it is probable that one of the photocells requires replacing.

What to do When Valves Fail to Light.

If the valves fail to light, either in voltage or power amplifier, look for blown fuses in the battery or motor generator output. If the voltmeter on the panel indicates normal conditions, an open circuit has occurred in the wiring to amplifier units. If some of the valves light and some do not, it is almost certain that the unlighted valves have burnt out and must be replaced.

Causes of Noisy Reproduction.

Excessive noisy reproduction may be due to :—

(A) Dirt and acid on the top of storage batteries (if used).

(B) Loose storage battery terminal connections.

(C) Loose connections to dry batteries, or dry batteries which have become old.

(D) Poor earth connections to the projectors.

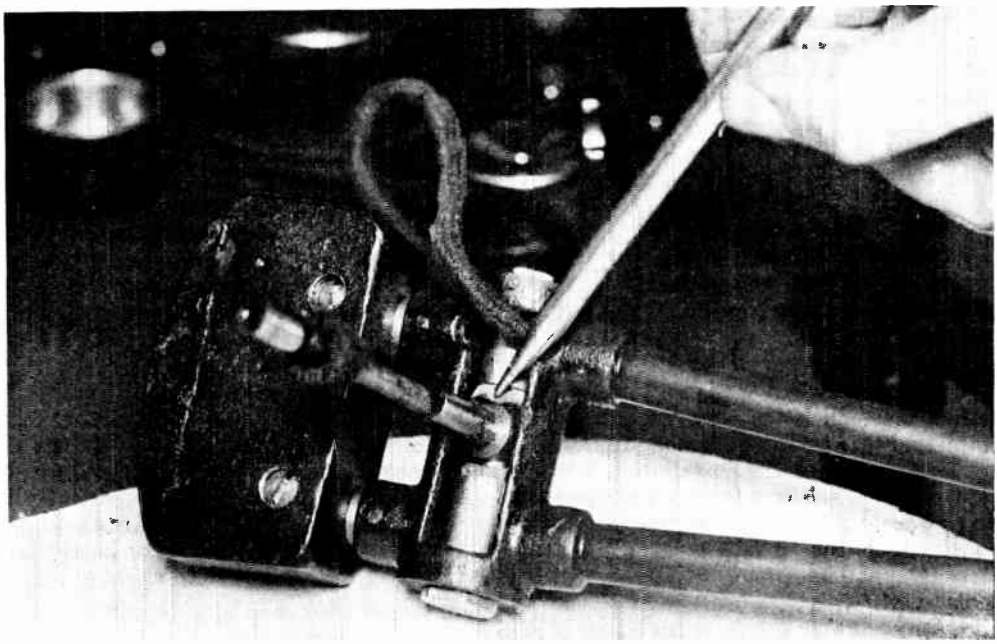


Fig. 44.—Synchronous Disc Tone-arm as Viewed from Below.
Note the correct position of the sponge rubber cushions.

(E) Dirty contact between valve base prongs and sockets.

(F) Dirty switch contacts.

Should an unusual whistling sound be heard with equipments employing UX-250 Radiotrons in the power amplifier, it is usually a sign that one of the Radiotrons has lost most of its "emission," resulting in greatly unbalanced plate current. The Radiotrons should be replaced by suitable spares.

Points to Check Each Day.

Always make certain that the supply of spare parts is complete and in good condition.

Each day check the following points :—

(1) Oil the projectors, turntables, chains, etc.

(2) Clean sprockets and sound gate, taking particular pains with the constant speed sprocket.

(3) Clean the outside lenses of the optical system if necessary.

(4) Check storage batteries for state of charge (if used).

(5) Check the exciter lamps for position and see that they are clean.

(6) Check voltages at the amplifier panel or motor generator panel.

(7) Run all projectors for five to ten minutes before starting the show.

(8) Check the sound from each projector by flicking a card across the light beam in the sound head.

If advice is required about any point, ask the service engineer. He is always available to help in any way possible. Always report to him any unusual occurrence connected with the equipment.

Above everything else, keep the equipment thoroughly CLEAN.

HOW TO PROVIDE ADEQUATE ILLUMINATION

By E. H. FREEMAN, M.I.E.E.

THE first article on this subject (which appears on page 404) dealt with the general principles of illumination, defining the various units employed and giving consideration to certain important features that must be kept in mind when designing a lighting installation—such as the avoidance of glare and of undesirable shadows. The detailed design of the installation with a view to the provision of adequate illumination was postponed, and the present article deals with this question.

Illumination of Vertical Surfaces.

Apart from flood lighting of buildings, the need for illumination of vertical surfaces is confined in general to a few special cases. Of these the most important is the lighting of pictures, diagrams or charts, and so forth, hanging on walls. Occasionally special lighting is required for vertical filing cabinets, for book shelves, storage bins, etc., but as a rule these do not need more light than is required to read titles or labels, and detailed designing is not necessary. Ordinary pendants or brackets spaced at reasonable distances provide all that is required.

The lighting of ordinary charts and plans hanging on walls can be carried out either by tilting ordinary type reflectors, or by the use of special angle reflectors as indicated in Fig. 2.

Picture lighting is a much more complicated problem and, whilst it is possible to apply the principles of ordinary illumination calculations to ensure adequate lighting, the difficulties of applying the light to obtain satisfactory results are very great. The glazing over the picture or its natural glossy surface gives varying reflections from different angles, and it is almost impossible to obtain really efficient lighting without some special system of indirect reflectors or flood lighting through distant wall or ceiling panels. Such schemes can rarely be applied to existing buildings, the structure of the building needing to be designed to provide suitable sources of light.

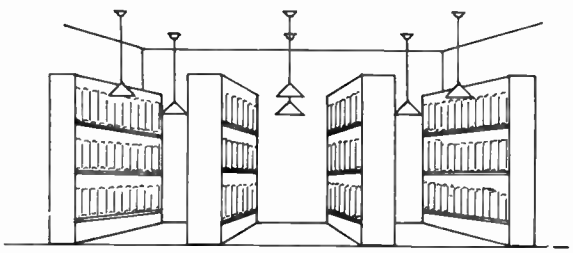


Fig. 1.—HOW PENDANT LIGHTS SHOULD BE ARRANGED FOR ILLUMINATING BOOKSHELVES.

As a rule these do not require more light than is necessary to read titles or labels and detailed designing is not called for.

Horizontal Surfaces.

The problem most usually needing solution is the lighting of horizontal areas, such as desk surfaces in offices, schools, etc., floor areas in shops, halls, factories, churches and similar buildings, and the general lighting of workshops or domestic rooms. Each class of building needs its own kind and intensity of illumination, and the notes here deal with the problem in a general way that apply to all such schemes.

Intensity of Illumination.

The first point to be decided when designing an installation is the intensity of illumination required, and this naturally varies for different buildings. The following examples will give a general guide as to the standards desirable, and the results that should be attained :—

Churches ..	4 to 5 candle feet.
Club rooms, halls, etc.	5 to 6 candle feet.
Shops	From 5 to 15 candle feet according to locality, class of goods sold, etc.
Shop windows ..	10 to 50 candle feet, also according to locality, etc.
Drawing offices ..	20 to 30 candle feet or more.
Library reading rooms.	8 candle feet.
Hotel reception rooms.	6 to 8 candle feet.
Office areas ..	5 to 6 candle feet if local lighting is also provided. 8 to 10 candle feet if only general lighting is provided.
Textile factories	5 to 10 candle feet according to class of work carried out.

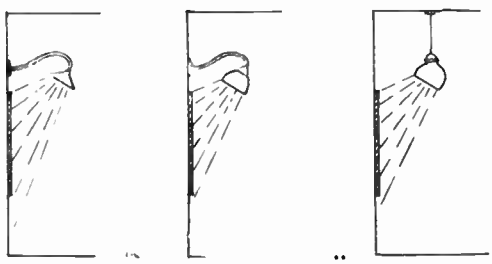


Fig. 2.—Lighting for Charts or Plans Hanging on Walls.

This can be carried out by tilting ordinary type reflectors or by the use of special angle reflectors, as shown.

Machine shops ..	For rough work, 6 to 8 candle feet. For fine work, 10 to 20 candle feet.
Corridors, staircases, etc.	2 to 3 candle feet.

It will be seen that the range of illumination is very considerable, but from the examples given the intensity of the light desirable in other cases can probably be estimated.

Total Quantity of Light Required.

Having decided the intensity of light required, the total quantity can be ascertained by multiplying the total floor area of the room or building to be lit by the candle feet considered desirable, based on the data given above. The result will give the total lumens required for the total area. This figure is the actual effective volume of light required and to this must be added such margin as is required to make good losses in reflection, absorption in wall surfaces, etc., and also an allowance to cover the gradual diminution in the light due to ageing of lamps, deposit of dust on fittings and lamps and finally due to the losses in the fittings themselves. The cumulative effect of all these losses is a formidable total and even with a well-designed scheme and favourable conditions these causes may involve a total loss of 50 per cent. or more of the actual light given out by the lamps.

The following examples indicate the general position.

Loss of Light by Reflection from Walls and Ceilings.

Very light colours ..	25% to 40%
Fairly light colours ..	35% to 50%
Fairly dark colours ..	50% to 70%

This factor is not of great importance if the room to be lit is of considerable dimensions in proportion to its height, i.e., if the length and width are several times the working height. This is usually the case with most large stores, factories or offices, and for such areas an allowance of 10 per cent. to 15 per cent. for losses due to reflection or absorption in walls and ceilings will be sufficient.

Losses Due to Fittings.

Good quality dispersive reflectors	15% to 20%
Enclosed unit fittings	30% to 40%
Opal glass bowl fittings	40% to 50%
Mirrored (opaque) bowl	50% to 70%
Losses due to dusty fittings	From 20% to 25% and upwards

It is rarely possible in practice to calculate any of these losses in advance with close accuracy. At the date when the lighting installation is being designed the exact colours of walls, for example, are frequently undecided. The care with which the installation will be maintained cannot be known and other factors of a similar kind make close calculation difficult or impossible. Frequently the type of fitting to be used may be modified at the last moment on account of cost, delivery, etc.

In designing the installation it is therefore usually impossible to do more than calculate the nett or effective lumens and to multiply this by some factor suitable to

the probable circumstances. This is not likely to be less than $1\frac{1}{4}$ to $1\frac{1}{2}$, and it is usually best to allow $1\frac{1}{2}$ to 2 times the nett lumens in preliminary calculations, even if conditions are likely to be of a satisfactory character.

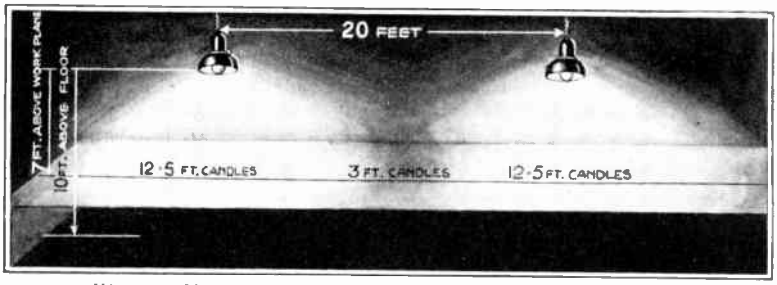


Fig. 3.—How Lighting Units Should be Spaced (1).
This shows the units spaced too far apart, giving uneven illumination.

Lamps can easily be cut down later on if larger than necessary, but cannot be increased if the wiring is too small due to underestimating the lamp sizes.

Spacing of Lighting Units.

The final step is to decide how to utilise the total lumens thus found to be necessary for adequate illumination, i.e., to decide on the number and spacing of the lighting units. This also depends on several considerations, the two decisive points being:

(1) Distance apart to ensure even illumination.

(2) Distance apart to suit method of fixing (on tie bars, roof trusses, etc.) or to suit architectural features (spacing of visible beams, ceiling decoration, etc.).

Types of Reflectors Available.

Of the above two items the first is the more important. A fairly wide latitude is possible, due to various types of reflector being available, some designed for concentrating the reflected light into a fairly narrow compass (suitable for high buildings), and others for diffusing the light over a wide area (suitable for positions where the ceiling height is not great).

Fig. 2 on page 405 shows several types of reflectors with their polar curves which indicate how the light from the lamp is concentrated or distributed by the reflector.

Use of Reflectors.

Concentrating reflectors are usually employed for special work, such as window lighting, whilst diffusing reflectors are more suitable for ordinary general lighting. With such reflectors, to ensure even lighting, the installation should be planned so that the distance between adjacent reflectors is not more than $1\frac{1}{2}$ to $1\frac{3}{4}$ times the distance from the reflector to the surface to be lit.

Thus if an office is 12 feet high the reflector can be hung with the lamp about 1 foot down from the ceiling, and the office desks will be about 2 feet 6 inches from the floor. The distance from the lamp to desk will thus be about 8 feet 6 inches, and the spacing of the fittings should be not more than $1\frac{1}{2}$ to $1\frac{3}{4}$ times this, i.e., from 12 feet to 15 feet apart.

Fig. 3 shows the effect of fixing the lighting units too far apart resulting in uneven and patchy lighting, and Fig. 4 the improvement resulting from fixing the units at the correct spacing. The size of the lamp units can obviously be reduced

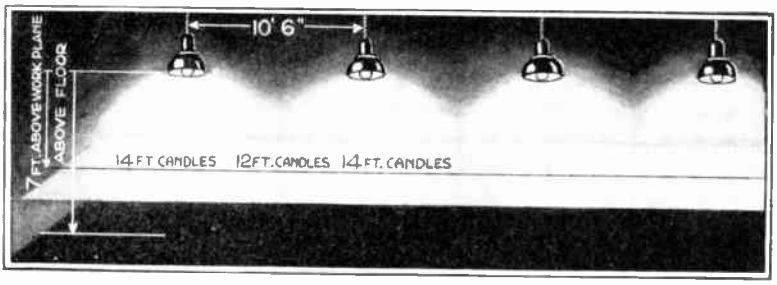


Fig. 4.—How Lighting Units Should be Spaced (2).
Here, the lighting units are correctly spaced, resulting in even illumination.

in this case to give the same average illumination as is obtained in the former scheme.

Spacing to Suit Architectural Features.

Having thus decided the approximate spacing to suit the height of the building, a further adjustment is frequently necessary to suit architectural features. Fittings in an office or shop, for example, must be arranged to fit into the spacing of windows or ceiling panels or to form features in some scheme of decoration. In factories the fittings must frequently be supported from roof ties, and should in any case form a symmetrical layout in relation to the roof construction.

Considerations of this character may involve a substantial alteration in the design of the installation, but usually the adjustments required are not sufficient to spoil a scheme. The margins allowable due to the use of various types of reflectors or to adjustments in the suspension heights, are in almost all cases wide enough to rectify any errors due to enforced alterations to the theoretical design to suit architectural features.

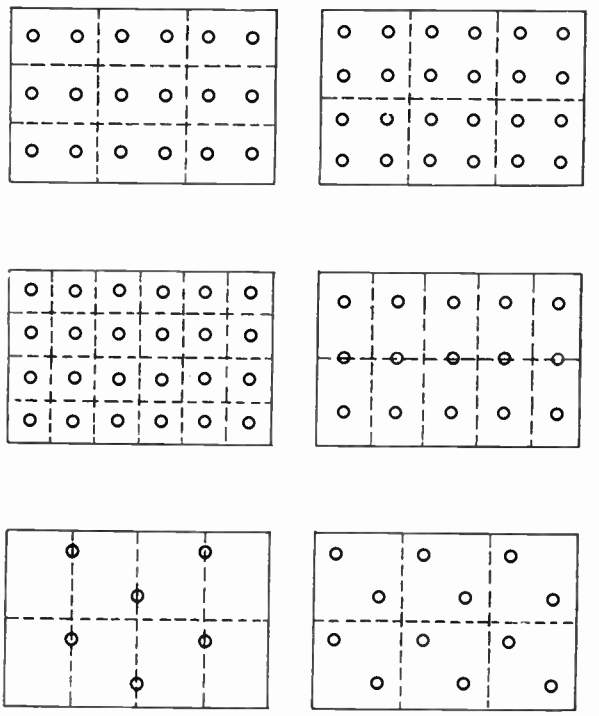


Fig. 5.—Six Different Schemes, each with a Symmetrical Arrangement of the Fittings to Suit Different Arrangements of the Ceiling Design (Indicated by Dotted Lines).

Alternative Arrangements.

In most buildings several alternative arrangements of the lamps will be found possible, each of which will give reasonably satisfactory results.

Fig. 5 shows six different schemes, each with a symmetrical arrangement of the fittings to suit different arrangements of the ceiling design (indicated by dotted lines), and any one of these might be suitable, according to the calculated ratio of working height to spacing distance. The scheme most suitable must be selected to suit all the factors involved.

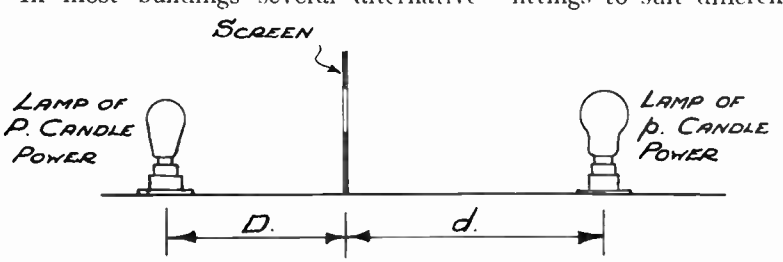


Fig. 6.—Testing for Illumination.

This is the simplest method and consists of a screen placed between a standard lamp or other source of light and the lamp which is to be tested. The lamp under test is fixed to a sliding base and is moved to and fro until the screen is judged to be equally illuminated on both sides. The illumination from the lamp can then be calculated by measuring the distances from the screen of the two lamps.

Number and Size of Units Required.

Having fixed on the arrangement and spacing of the lighting units, the positions can be marked out on the plan of the building and the total number of units required for the complete area is then known.

By dividing this number into the total lumens required, as calculated earlier, the lumens that must be given out by each unit is obtained and the size of lamp to be used is then found by reference to a lamp catalogue which gives the lumens per lamp for various sizes and voltages. The design of the installation is thus completed, the spacing, type and size of the lighting units all having been calculated.

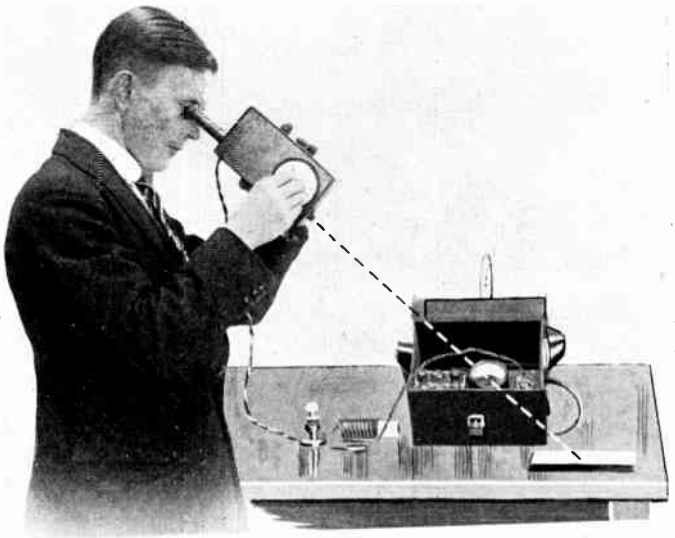


Fig. 7.—LUXOMETER PORTABLE PHOTOMETER IN USE. (*Everett, Edgcumbe.*)

The Procedure—Step by Step.

Summarising the steps in the design of the lighting scheme the procedure is thus :—

(1) Decide the intensity of illumination (candle feet) required to light the area.

(2) Measure the total floor area to be lit.

Fig. 8.—LUXOMETER COMPLETE. (*Everett, Edgcumbe.*)

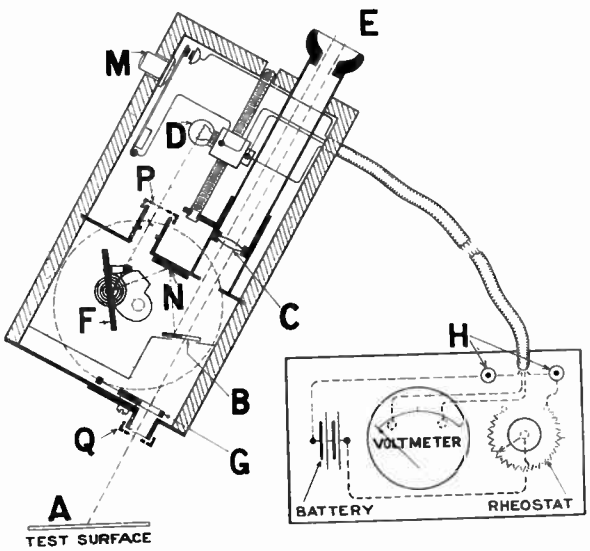


Fig. 9.—INTERIOR VIEW OF THE LUXOMETER. (*Everett, Edgcumbe.*)

A, test surface ; B, half silvered mirror ; C, focusing lens ; D, internal comparison lamp ; E, viewpoint ; F, adjustable comparison surface ; N, mirror.

(3) Ascertain the total quantity of light required (nett lumens) by multiplying the candle feet by the floor area.
(4) Correct this nett figure to allow for losses in reflection, absorption in walls and ceilings, dust on fittings, etc.

This correction will mean increasing the nett lumens 1½ to 2 times.

(5) Decide the spacing of the lighting units to suit :
(*a*) the height of the room ;
(*b*) the architectural features,
and thus settle the number of lighting units to be used.

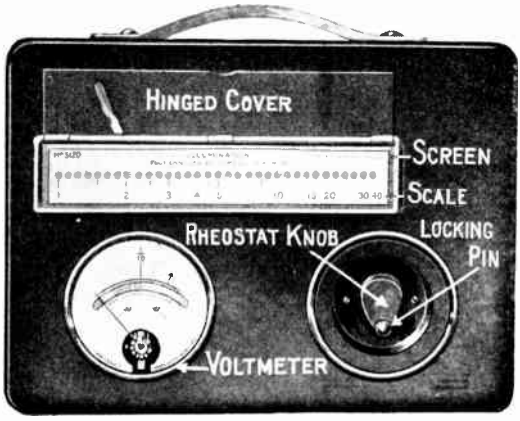


Fig. 10.—ANOTHER TYPE OF PORTABLE PHOTOMETER. (*Edison Swan Electric Co.*)
Closed ready for carrying.

(6) Ascertain the lumens required per unit by dividing the total lumens (Item 4) by the number of units (Item 5).
(7) Select the size of lamp required that will give out the lumens as calculated (Item 6).

Testing for Illumination.

Before considering the application of the general principles of illumination design to special cases some reference to the methods of testing for illumination will be desirable.

It has already been stated in the earlier article that the unit of illumination is the standard candle and that the illumination obtained for a source of light varies as the square of the distance from that source. The various instruments designed for testing illumination and known as photometers mainly depend on this fact, comparison between a known and unknown source of light being made and the relative strengths of the sources being then calculated.

Simplest Form of Test.

In its simplest form a screen is placed between a standard lamp or other source of light and the lamp which is to be tested (see Fig. 6).

The lamp under test is fixed to a sliding base and is moved to and fro until the screen is judged to be equally illuminated on both sides. The illumination from the lamps can then be calculated by measuring the distances from the screen of the two lamps.

Thus if P is the candle-power of the standard lamp
D is the distance of this lamp from the screen,
p is the candle-power of the lamp under test,
and d is the distance of the lamp from the screen
we shall have, as the illumination varies as the square of the distances,

$$\frac{P}{D^2} = \frac{p}{d^2}$$

$$\therefore \quad p = \frac{d^2}{D^2} \times P$$

and as all these are known the value of p can be calculated.

Thus if an 8 c.p. lamp were used as a standard and the distances of this lamp and the tested lamp were 2 feet and 5 feet respectively from the screen, the c.p. given by the tested lamp would be :—

$$\frac{8 \times 5^2}{2^2} = 50 \text{ c.p.}$$

An Improved Method of Testing.

In practice this simple photometer is rather difficult to use. It is not easy to judge equal illumination by looking first at one side of the screen and then at the other, and a great improvement was devised by Bunsen, who added a grease spot in the centre of the screen. This reflects less light and transmits more

light than the white, ungreased screen, and therefore shows as a dark spot when lit from one side only. When lit equally from both sides the grease spot apparently disappears, as the reflected light plus the transmitted light from the two sides, amount to the same total. It is therefore only necessary to look at one side of the screen and to move one lamp until the spot fades out. The candle-power can then be calculated as on page 569.

Portable Photometers.

In recent years, as a result of the steady development of the science of illumination and the consequent desire for accurate records, many portable forms of photometer have been produced. Of these the Everett Edgcumbe "Luxometer" is a good example.

The instrument itself is shown in use in Fig. 7, and as arranged for convenient transport in Fig. 8. The principles of operation can be followed from Fig. 9, which also shows the internal electrical connections.

Method of Using Instrument.

The test surface A, which receives the illumination to be measured, is viewed by the observer at E through the clear portion of the half-silvered mirror B and the focusing lens C. At the same time, the light from the internal comparison lamp D falls upon the adjustable comparison surface F, which is likewise viewed from E by reflection at the mirrors N and B. The brightness of F can be varied by turning an external milled knob until it exactly matches the brightness of the test surface A as evidenced by the disappearance of the line of demarcation between the two when viewed from E. The scale, which is so graduated that the illumination at the surface A can be read direct in foot-candles, is shown in Fig. 8.

The range is extended by the use of neutral filters carried in the rotating holder G, which reduces the transmitted light to 1/10th, 1/100th and 1/10000th, thus giving maximum ranges of 2, 20, 200 and 2,000 foot-candles respectively.

Another similar portable instrument is supplied by the Edison Swan Electric Company, and is illustrated in Figs. 10 and 11. The white screen shown at the top of the instrument consists of two thicknesses of paper, one only of which is perforated.

The screen is illuminated from inside from a small electric lamp from one end,

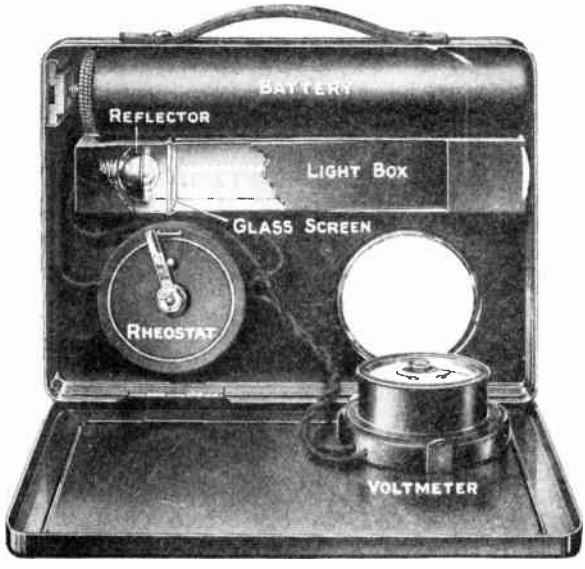


Fig. 11.—EDISON SWAN PORTABLE PHOTOMETER. The screen is illuminated from inside by a small electric lamp at one end and the holes in the screen vary in brightness. The point at which the brightness of the holes corresponds with the brightness of the exterior surface indicates the illumination on this surface. The screen is calibrated to read direct in foot-candles.

and the holes in the screen vary in brightness, those near the lamp appearing bright in relation to the exterior surface of the screen and those remote from the lamp appearing relatively dark. The point at which the brightness of the holes corresponds with the brightness of the exterior surface indicates the illumination on this surface and the screen is calibrated to read direct in foot-candles.

Four "zero" positions are obtainable —one for direct readings in foot-candles, others for one-tenth, one hundredth or double the direct reading scale.

FITTING ADDITIONAL POINTS OF SUPPLY

By T. LINSTEAD.

ELECTRICITY in most districts is to-day supplied under various schemes, and in most cases so cheaply that it is a false economy to be too sparing in the question of additional points of supply in the home. Many a bright light may be shed in dark places, and many a laborious duty converted to a pleasurable pastime by its aid, and not least is the added comfort and air of friendly welcome that is imparted by its use along properly directed channels.

The Entrance.

One particularly dark spot in an otherwise well-lighted house is invariably found at the porch or exterior of the front door. A dark or dismal entrance does not inspire a feeling of welcome, but rather the reverse.

A Porch Lamp.

The type to be used here depends upon the manner in which the entrance is constructed. If there is any possibility of the lamp being exposed to the weather, an enclosed fitting should be used, while any of the usual makes of lanterns may be safely used in a sheltered position. One such lantern for use only in sheltered positions or enclosed porches is shown in Fig. 1.

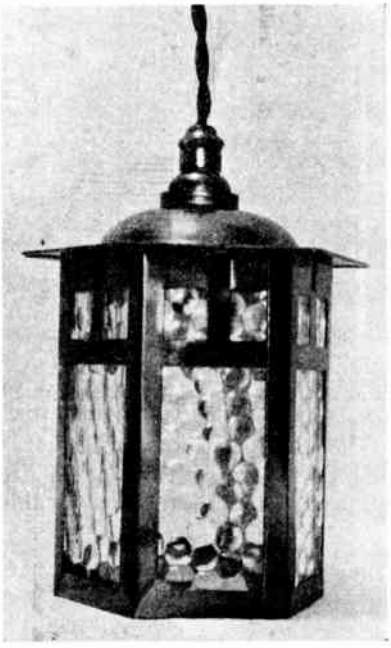


Fig. 1.—A PORCH LAMP.

This type is suitable for use in sheltered positions or enclosed porches where there is no likelihood of the lamp being exposed to the weather.

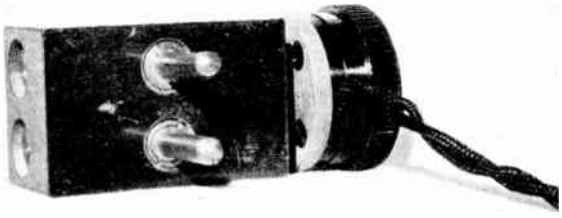


Fig. 2A.—A THREE-WAY TWO-PIN PLUG ADAPTER.

This enables three appliances to be supplied from one socket. The third pair of sockets is at the rear of the two pins.

Running Cable Out to Porch.

Assuming that the lead cable has been fixed to a position inside the front door, a suitable means of passing the cable to the exterior must be found. The construction of a building is usually such that the weight above the door is carried on a concrete lintel and it will be useless to attempt making a hole through this, and the brickwork immediately above is usually in the floor. The best method is to bore a hole of sufficient size in a corner of the wooden frame. If a porch exists, the cable may then be fastened along its ceiling and

Fig. 2B.—Using a Three-way Two pin Plug Adaptor.
Showing how a fan can be used from a wall socket and set in motion by a switch without having to insert the plug in the socket each time.

terminated at a ceiling rose or wooden block to which the lantern may be hung.

remove the lamp-holder.

Hold the bracket in position on the wall, and shape the cable around the swan neck. Cut the cable to the required length, being sure that sufficient is left to make the connections to the holder. Remove the lead casing for about 3 inches from the end and thread the cable through the swan neck, commencing from the back plate, until the plate fits close to the wall, with the slot in the back plate fitting neatly over the cable. Screw the bracket to

A Watertight Fitting for an Exterior Light.

Where no porch exists, the method is somewhat different and great care must be taken that water is not allowed to find its way to the unprotected wires. For this purpose the fitting is provided with a swan-neck bracket, and the lamp enclosed in a watertight glass well.

Having brought our cable through the door frame and fixed it on the wall to the position chosen for the fitting,

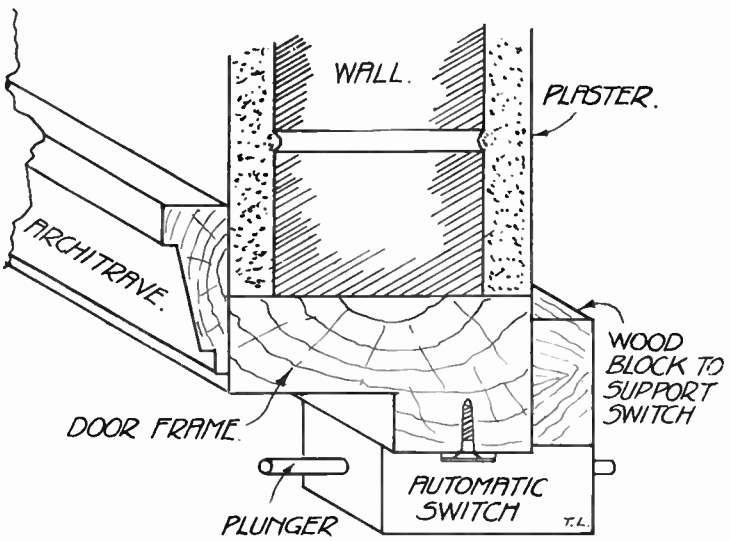


Fig. 3A.—Fixing an Automatic Door Switch.
The switch is screwed to the head of the door frame in such a position that the closing of the door depresses the push to its fullest extent without strain. It may be necessary to fix a small wood block at the back if the head of the door frame is not wide enough.

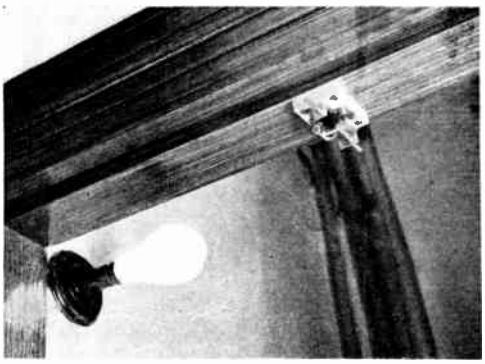


Fig. 3B.—AUTOMATIC DOOR SWITCH IN POSITION.
This shows the switch with the cover removed and the cupboard door open.

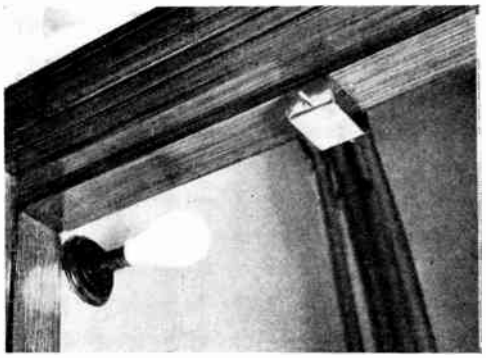


Fig. 3C.—AUTOMATIC DOOR SWITCH IN POSITION.
Showing the cover on and the switch complete as it would appear normally.

the wall, using Rawlplugs to ensure a sound fixing.

Remove the insulation from the wires for about $\frac{1}{2}$ inch from the end, and connect them to their respective sockets in the lampholder. Place a lamp in the holder and fix the glass cover between the rubber rings provided, thereby making the whole fitting completely watertight.

Lighting Up Cupboards.

These are another of the most neglected spots. How often one finds on opening a cupboard door that the light of the room is in such a position as to be completely blacked out by the person framed in the door opening. Or it may be that a linen cupboard is placed on a landing with the hall light projected to one side, and yet how simple to so arrange a light inside the cupboard that on opening the door the light is switched on, and on closing is immediately extinguished. The amount of current that would be used in removing or replacing an article in a cupboard so fitted is so small

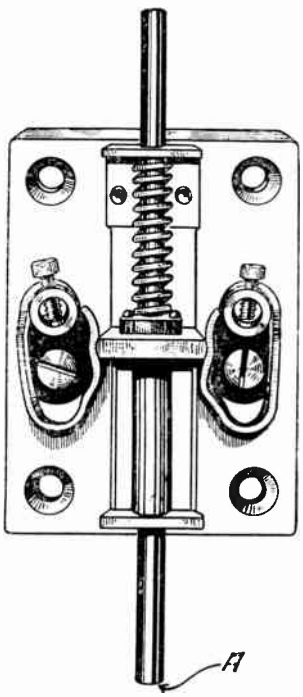


Fig. 3D.—AN AUTOMATIC DOOR SWITCH.
This is suitable for fixing to a cupboard door, for when the door is shut the contacts are held apart by pressure at *A* and the light is switched off. Immediately the door is opened a spring exerts its pressure, brings the contacts together and the light is switched on.

that a thousand openings and closings would make no appreciable increase in the electricity account.

An Automatic Door Switch.

A switch suitable for fixing to a cupboard door is shown in Figs. 3A to 3D, and is composed of a pair of contact-points operated by a spring. When the door is closed the contacts are held apart, but immediately the door is opened the spring exerts its pressure, brings the contacts together, and switches on the light.

Reference is made elsewhere in this article to the wiring of a new point, and these instructions apply in this case, the only exception being that the wires feeding the switch are carried to a position at the top of the door.

The automatic push is next screwed to the head of the frame in such a position that the closing of the door will depress the push to its fullest extent without strain. It may be necessary to fix a wooden block

at the head of the door frame to support the switch, and Fig. 3A shows how this should be done.

Next remove the cover from the switch, and having bared the ends of the wires to be connected to the switch, secure them each in their respective sockets and replace the cover.

Electricity in the Larder.

Here we have another part of the house which may come in for its share of electrical attention. A small electric fan so placed inside that a current of cool air is kept circulating through the place where fresh food is stored, is no small boon in times of excessive heat, and would merit its small cost being expended in any home, whereas the heavy expense of any of the usual makes of refrigerators would be prohibitive in a small household.

Supplying a Fan to the Larder.

This may be done in either of two methods. If the fan is required to be a fixture, a pair of wires may be run to the inside of the larder, and connected directly to the fan. This can be done in the same manner as if the fan were a lamp, one wire being taken from the black wire of the nearest light and connected to the fan. Another wire should be connected to the live wire of the nearest switch and connected to one side of a new switch which controls the fan. From the other terminal of this switch a wire should be joined to the other terminal of the fan.

How to find the live wire of a switch is explained on page 117.

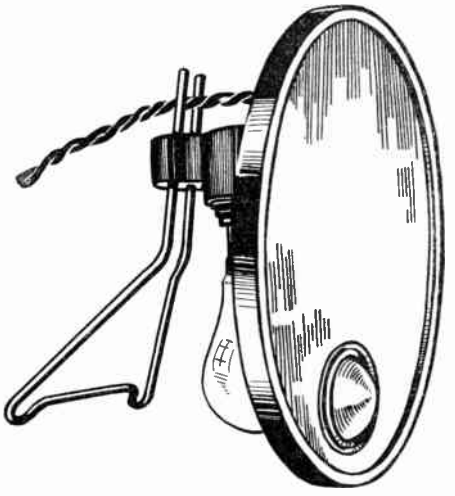


Fig. 4A.—AN ILLUMINATED MIRROR.
This is to cut out shadows while shaving. Note the frosted lens for concentrating light.

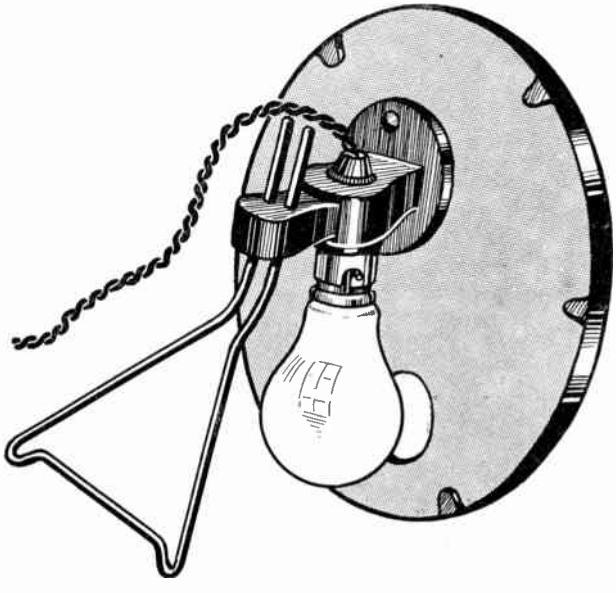


Fig. 4B.—AN ILLUMINATED MIRROR.
Back view, showing the mirror with lamp in position.

An Alternative Method—Using a Plug.

Should the provision of new wiring entail more work than it is convenient to attempt, the same result can be achieved by using a nearby live plug if one is in existence. Fig. 2A shows a very useful adapter that can be brought into use in many places. It is made in several combinations to enable two or more appliances to be connected to it.

Using a Plug Adapter.

For the purpose of supplying our fan we can use a piece of twin flexible cable with one pair of ends prepared and connected

to the terminals on the fan. The other pair of ends is prepared and connected to the sockets in one of the plugs provided with the adapter. This is inserted in its sockets on the adapter, and the latter placed in the skirting socket.

The advantage of the permanent method of fixing, over the latter, is that the fan can be set in motion by a movement of the switch, whereas in the latter the plug must be inserted in its socket each time the working of the fan is required, unless a switch is provided on the fan.

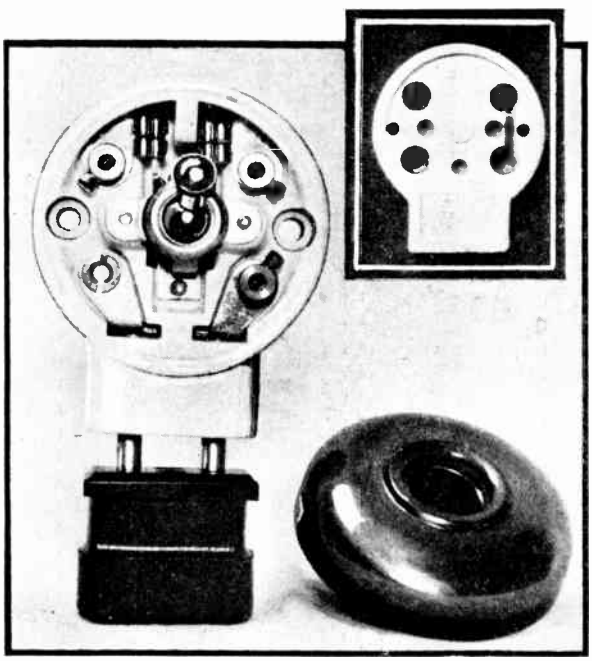


Fig. 5.—A Combined Switch and Plug.
This enables you to have the light either "on" or "off" while another appliance is being used. By means of the bridge shown in the inset the sockets are rendered "live" whatever the position of the switch.

An Illuminated Shaving Mirror.

Another instance of usefully applied light is in the bathroom. A ceiling light if placed in the correct position, namely, as near to the window as possible (this is to prevent shadows being thrown on the glass) is hardly ever an ideal position to assist in the daily discomfort of shaving. The main fault is that the under side of the chin is thrown in shadow.

Cutting Out the Shadows While Shaving.

To secure the best conditions, the face must be illuminated from the front, and at the same time being reflected in a mirror. Figs. 4A and 4B show a mirror designed on these lines. Upon examination it is seen that it consists of an ordinary mirror with a circular hole cut at the bottom. In front of this hole is placed a frosted lens. Fixed on the back of the frame is a lampholder, so placed that the light is absorbed by the lens and concentrated on the lower part of the face, but avoiding any glare to the eyes. A length of flex and an adapter is supplied and can be inserted in an ordinary lampholder. If necessary the adapter can be substituted for a two-pin plug and used with a live socket.

An Improvement in the Garage.

If the garage is fitted with electric light several uses for electricity may have been apparent to the owner, but have been discarded owing to the lack of suitable connections. To be compelled to remove the lamp from its holder is at all times inconvenient, and at night almost impossible since there may be no other means of illumination.

By means of the following small addition to the wiring, a useful adaptation can be made.

Fixing a Combined Switch and Plug.

Fix a length of single lead-covered wire across the ceiling from the ceiling rose, and continue down the wall to the switch. Remove the ceiling rose or batten holder together with its fixing block. Next strip and prepare the end of the new wire and twist it together with the black or "dead" wire. Replace the fixing block and ceiling rose after clamping the wires in their original terminals.

The switch has now to be replaced by a combined switch and plug of the type shown in Fig. 5, and must therefore be

removed with its block. Examine the new switch plug and you will find that it has two sockets for the insertion of a plug and three smaller sockets with clamping screws. Having made an additional hole in the block to correspond with the extra terminal socket, strip and prepare the end of the new wire. Thread the three wires each through the block with the new wire in the last made hole and the live wire in the hole connected to the bridged terminal. Fix the block and insert the wires in the sockets of the switch in the order shown in Fig. 6.

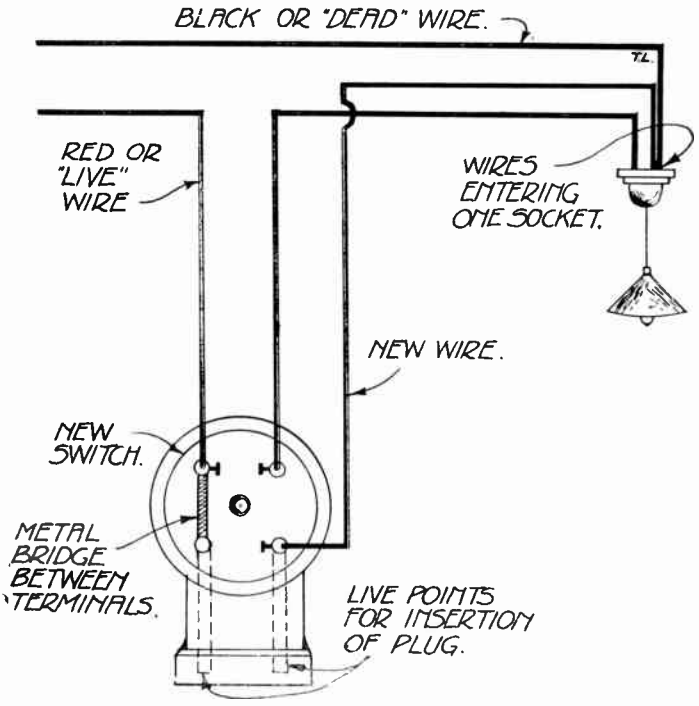


Fig. 6.—How to Connect up the Combined Switch and Plug.

We now have a "live" pair of sockets for the insertion of a plug, and they remain so, irrespective of the switch controlling the light being "on" or "off." It will thus be seen that this can be used for such appliances as a radiator heater or hand lamp, without switching off the light.

VOLTS—E.M.F. AND P.D.

The electromotive force, or E.M.F., of an electrical supply is the total driving force in the circuit. It is measured in volts. The E.M.F. measured at the terminals of an electrical supply, whether it be a battery, dynamo or public supply main, is the same as the potential difference, or P.D., when no current is being taken from the source of supply. When, however, a current is drawn from the supply, the P.D. at the terminals is always less than the E.M.F. Consider a practical example. A house lighting dynamo is supplying 20 50-watt lamps, and a voltmeter connected across the terminals of the dynamo gives a reading of 102 volts, while the P.D. measured at a lamp socket in the house is exactly 100 volts. When all the lamps are switched off, the dynamo voltage is 110 volts. The E.M.F. of the dynamo s 110 volts, while the P.D. at the terminals of the dynamo, when supplying 10 amperes, is 102 volts. If all the lamps were switched off, the voltage measured at the lamp holder would be the same as the E.M.F. of the dynamo, namely 110 volts.

The difference between the no-load E.M.F. and the P.D. on load gives the voltage necessary to overcome the internal resistance of the source of supply. In the above example the difference is 8 volts for a load of 10 amperes. The internal resistance of the dynamo is therefore $\frac{8}{10}$ or .8 ohm.

This result is obtained by applying Ohm's Law:—

$$\text{Current} = \frac{\text{Voltage}}{\text{Resistance}}$$

$$\text{or Resistance} = \frac{\text{Voltage Drop}}{\text{Current}}$$

ELECTRIC RAILWAYS

By JOHN DUMMELOW, B.A. (CANTAB.)

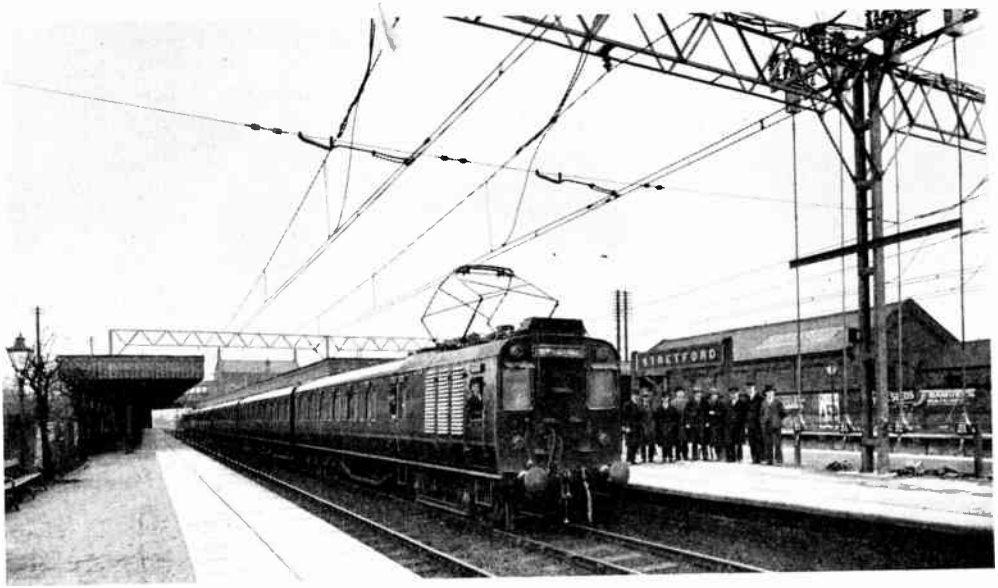


Fig. 1.—SIX-COACH MULTIPLE-UNIT TRAIN (1,500 VOLT D.C.).
Showing pantagraph and compound catenary overhead construction. (*G.E.C.*)

ELECTRIC trains may be driven either by electric locomotives or by motors carried on the passenger coaches (motor coaches). Current may be supplied by :—

(1) Storage batteries carried on locomotives and charged at fixed supply points,

(2) Electric generators driven by diesel engines and carried on the train, or

(3) Track conductors fed from a high tension transmission system through sub-stations.

The first two methods avoid the necessity for elaborate track equipment. On the other hand, with diesel-electric trains the space limitations prevent large quantities of power being generated as cheaply as in a fixed power station, and battery locomotives are only feasible where the average demand on the batteries is low. The track conductor system thus holds the field.

The First Electric Railway.

The first electric railway was opened 50 years ago in Germany, and to-day over 10,000 route miles are electrified, chiefly in the United States (1,870 miles), Switzerland, France, Italy and Germany. In Great Britain 496 miles of surburban lines have been equipped, and the electrification of the whole railway system has been suggested by a Ministry of Transport Committee.

Systems of Electrification.

Direct current, single-phase alternating current and three-phase alternating current are all used for electric trains in different parts of the world.

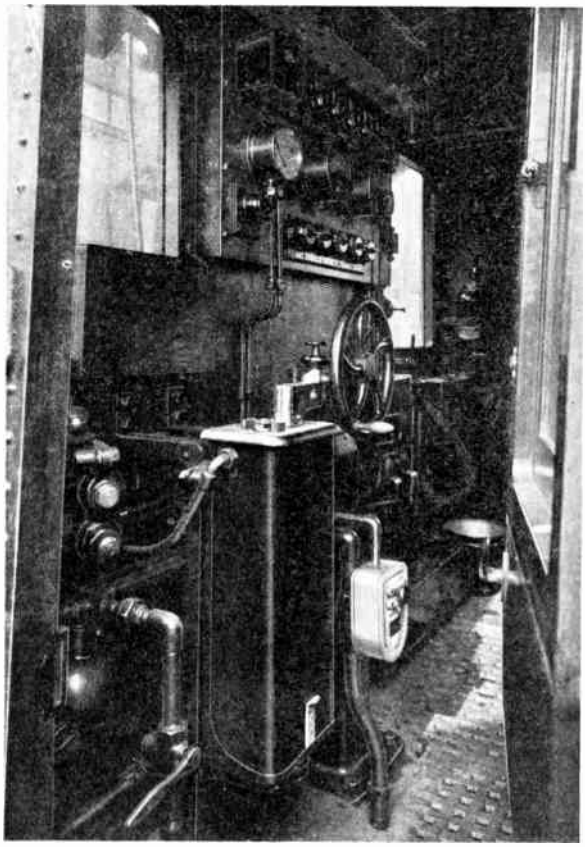


Fig. 2.—A Driving Cab in a Motor Coach of an Electric Train.

Note the master controller with its "dead man's handle." (*G.E.C.*)

Only Direct Current Used in this Country.

D.C. at 1,500 volts has been standardised for main lines in Great Britain (and also France, Holland, Belgium and elsewhere), and in the United States 3,000 volts D.C. was adopted for a trans-continental route of over 800 miles electrified recently. On suburban lines D.C. from 600 to 1,500 volts is almost universal. The direct current system only will therefore be dealt with in this article.

For suburban elctrification motor coaches and trailers are generally used, because :—

(1) The adhesive weight is a maximum,
(2) Trains can be made up of any number of coaches (the "multiple-unit" system), the motor capacity being always sufficient, and
(3) The trains can be driven from either end, thus increasing the capacity of the termini.

The varied types of passenger rolling stock used on main lines must be hauled by electric locomotives, and electric locomotives are also essential for goods trains and shunting operations.

How the Power Reaches the Train.

The supply from the three-phase alternating current transmission lines is stepped down by transformers and converted to direct current by rotary converters or mercury arc rectifiers at sub-stations, spaced 2 or 3 miles apart on suburban lines and 10-20 miles apart on main lines. The direct current from the sub-stations is fed through cables to the positive track conductor (either a third rail or an overhead wire), from which it is collected by the train. The return path for the current is provided by the running rails or by a negative conductor.

METHODS OF "PICKING UP" CURRENT.

Below 1,500 volts the large currents that may be required necessitate a conductor rail along which slide collector shoes fixed underneath the train. For higher voltages and for complicated sidings bow collectors or pantagraphs on the roof of the train collect current from an overhead contact wire. The return circuit is usually provided by the running rails, via the axles and wheels, but the small voltage drop required by the B.O.T. Regulations necessitates a negative conductor rail on some low voltage systems.

Third-rail Systems.

Positive or negative conductor rails are of high conductivity steel with a specific resistance about 6 or 7 times that of copper. The contact surface may be at the top, at the side, or underneath.

The rails are carried on porcelain insulators mounted on the sleepers, the under-contact type being supported with its insulators from cast-iron brackets. The rail joints are electrically connected by flexible copper-stranded bonds.

Where the running rails are used for the return circuit, stranded copper bonds are necessary at the joints and cross bonds at frequent intervals between the rails.

Collector shoes are made of cast iron or cast steel and are supported from the coach underframe or the axle boxes. Contact is maintained by springs or, with top-contact rails, by the weight of the shoe. On multiple-unit trains trailers are often equipped with shoes as well as motor coaches; all the shoes on the train are connected by a power cable to bridge the gaps at points, level crossings, etc.

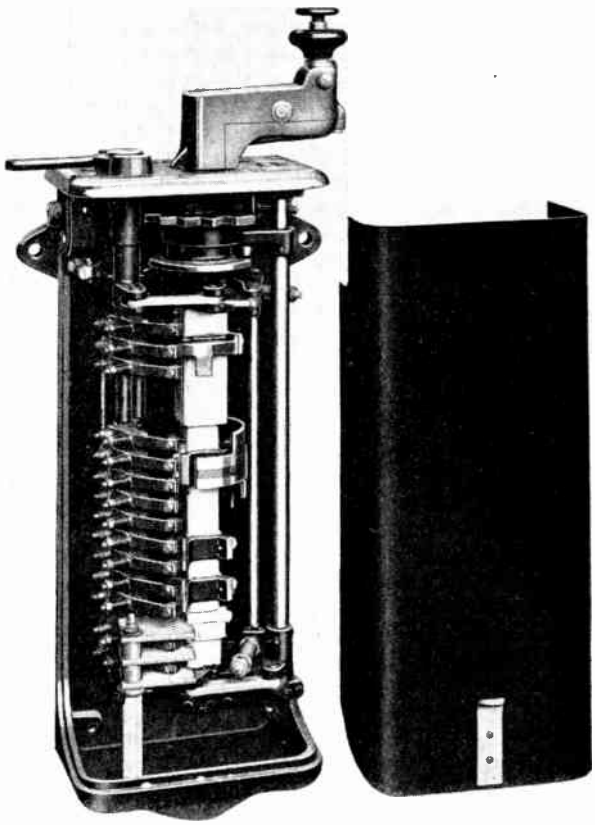


Fig. 3.—A Master Controller (with Cover Removed) for a Multiple-unit Train.
Showing the main (right) and reversing (left) handles. (*G.E.C.*)

Overhead Systems.

The contact wire is usually of hard-drawn copper, supported by short "droppers" from a catenary of stranded steel, which is suspended from supports about 150-300 feet apart.

A compound catenary is often used with the contact wire resting on droppers hung from intermediate small catenaries, which in turn are suspended between long droppers from the main catenary. The catenaries may have a considerable sag, but the contact wire must be as level as possible for efficient current collection. The supports may consist of bracket arms on steel poles or of cross catenaries or gantries between pairs of poles.

The framework of bow collectors (two parallel members with a curved "bow" across the ends) and pantagraphs is of light tubular steel and is fixed to shafts carried on a channel-steel base which is mounted on porcelain insulators. The framework can be raised or lowered by compressed air; the pneumatic valves are controlled electrically from a switch in the driving cab. A fairly uniform contact pressure at different heights is maintained by springs. The bow itself consists of an aluminium contact strip, but with pantagraphs the contact strip is of copper and is carried in a steel "pan" or "skate." Each motor coach or locomotive is equipped with one or two current collectors and also with lightning arresters.

ELECTRIC TRAIN MOTORS.

Series-wound motors are used, giving

(1) A high free-running speed,

(2) A high starting torque, which for a given current is independent of fluctuations in the line voltage but falls off as the load rises and the speed increases, and

(3) A speed that under a given load varies as the terminal voltage.

The output of the motor equals the product of the torque and the speed, so that high rates of acceleration can be used without excessive power demand. Starting is effected by inserting resistances, consisting of cast-iron grids, in the motor circuits. Main fuses and automatic circuit-breakers protect the equipment from short circuits and overloads.

Motor coaches have 2 or 4 motors, each developing up to 350 h.p. on the one-hour rating. Moderate and high-speed locomotives may have four or more motors, each developing 150-1,000 h.p. on the continuous rating, the maximum total output being at present about 6,000 h.p.

Geared Motors.

On multiple-unit trains and slow and moderate speed locomotives the motors are generally axle-mounted, one side of the motor frame being supported on the axle by suitable bearings and a nose on the other side resting on the bogie. Power is transmitted to the wheels by single-reduction spur gearing. For high-speed locomotives the heavier motors must be mounted on the frame to relieve the axles of dead weight and raise the centre of gravity. As the frame is spring-supported a flexible transmission is necessary.

The motors usually have solid frames of cast steel, and the armature shafts may run in either sleeve or roller bearings. Small motors have a two-circuit winding with 4 field poles, but for locomotives a multiple-circuit lap winding with 6 poles is advisable. Commutating poles are almost always used and are essential for weak field control. The motors are either self-ventilated by means of an internal fan or forced-ventilated (on locomotives) by an external blower.

Gearless Motors.

For high-speed locomotives gearless motors may be used, either :—

(1) A number of small bi-polar machines with their armatures mounted directly on the axles and their field poles built into the bogie, or

(2) One or two large multi-polar machines (mechanically similar to stationary motors) mounted on the frame.

The motors are forced ventilated.

Motor Operation.

When two motors are used they are connected first in series, which halves the current taken from the line, the terminal voltage and the maximum speed, and then in parallel for full speed (" series-parallel " operation) ; the current per motor and the resulting torque are unchanged throughout. Four motors may be operated as two independent series-parallel groups. For 1,500 volts upwards on passenger trains four motors are usually permanently connected in pairs in series, the terminal voltage of each being halved and the two pairs being operated in series-parallel. Four motors may also be operated with three combinations—full series, two series pairs in parallel, and full parallel ; six motors also give three combinations. The last two methods are suitable for freight locomotives where a number of slow speeds are essential.

The full resistance is in circuit when each connection is made and is cut out step by step until an economical running speed with no rheostatic losses is reached. Further economical speeds may be obtained by weakening the motor fields and thus increasing the speed at any of the normal combinations.

Energy Consumption.

The output of the motors has to overcome :—

(1) The friction of the track, axles and air, and

(2) The weight of the train when ascending an incline.

It has also to provide power for acceleration. The train motion is made up of periods of acceleration, constant speed, coasting retardation, and braking. The current used in acceleration is converted into kinetic energy, part of which is used on coasting and the remainder dissipated in heat in the brake shoes.

The energy consumption for a given schedule depends on :—

(1) The distance between stops and the configuration of the tracks,

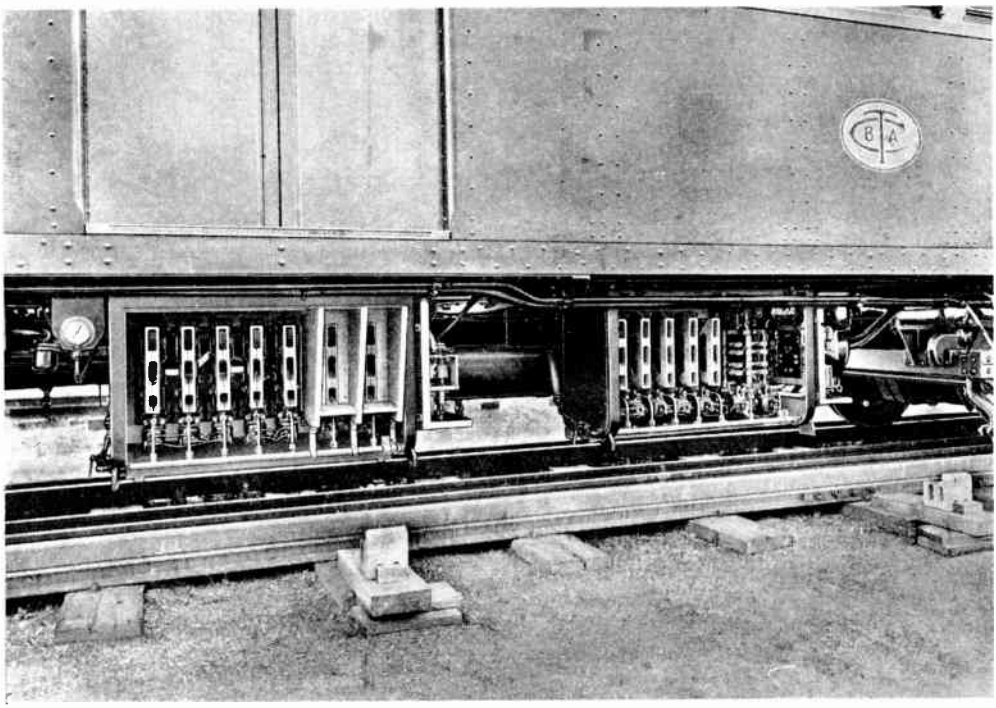


Fig. 4.—Groups of Contactors (Unit Switches), Accelerating Relay and Reverser, Mounted on Underframe of Motor Coach. (*G.E.C.*)

(2) The acceleration, retardation and maximum speed specified, and

(3) The type of train and equipment.

From the speed-time curve for a given schedule and the characteristic curves of the motors the energy consumed can be calculated.

CONTROL GEAR.

Driving cabs are provided on all motor coaches and locomotives, and also on some trailers. They contain a master controller from which the motors are operated by :—

(1) All-electric (or "electro-magnetic") control, up to 600 or 800 volts, or

(2) Electro-pneumatic control, on the higher voltages.

On multiple-unit trains the acceleration is nearly always automatic, being governed by a relay; jumper cables between the coaches enable any number of motors to be controlled in unison by one driver.

Control Apparatus.

For each motor group the various connections are made by a set of switches or "contactors," operated either as separate units or as a group by cams mounted on a common shaft. Each contactor consists essentially of a fixed and a moving contact. With unit switches the moving contact is actuated by the plunger of an electro-magnet or by the piston of a compressed air cylinder, to which the air supply is controlled by magnet valves. Cam-shafts are driven either by a low-voltage motor under the control of a contactor or by a pneumatically operated rack and pinion.

The direction of motion of the motors is reversed by a drum-type throw-over switch or by a group of contactors operated similarly to the switch-groups.

The master controller has two drums, main and reverse, each with its own controlling handle and interlocked so that the

train cannot be reversed unless the motors are disconnected from the supply. The drums carry a number of insulated segments, which, when rotated, make contact with fixed spring fingers, thus making or breaking the control circuits.

With electro-pneumatic control the control current is supplied at low voltage (e.g., 14-600 volts) from a battery, motor generator, or other auxiliary supply; the compressed air is obtained from a motor-driven compressor.

How Automatic Acceleration is Obtained.

Automatic acceleration is governed by a current limit relay embodying a coil connected in the motor circuit with a plunger carrying contacts in the control circuit. When a step of resistance is cut out the current in the motors rises, and when it falls to a definite value the relay closes the appropriate control circuits to operate the next contactor.

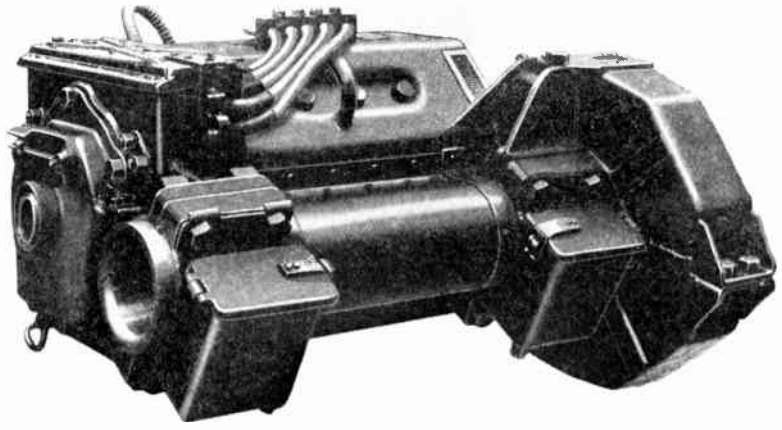


Fig. 5.—A 105 H.P. 500-VOLT D.C. GEARED TRACTION MOTOR. (*G.E.C.*)

Where the Control Gear is Housed.

On locomotives the control gear is mounted in the body. On motor coaches it may be mounted in a compartment behind the driving cab or on the underframe. The doors of compartments containing high voltage apparatus are electrically interlocked with the current collector so that they cannot be opened unless the train is isolated from the line.

Operation.

By moving the main handle of the master controller, magnet coils are energised causing their plungers to operate contactors either directly (all-electric control) or by opening compressed air valves (electro-pneumatic control). With automatic acceleration the handle has only three or four positions and can be moved right across, the intermediate operations taking place automatically.

BRAKING.

Standard air or vacuum brakes are used. In the event of an accident to the driver a small knob in the main master controller handle (the "dead man's handle"), or the handle itself, which is normally depressed, is released; power is cut off from the control circuits, and the brakes are applied automatically.

On mountain railways or main lines with considerable gradients trains may be braked electrically, the kinetic energy being utilised to operate the motors as generators when running downhill. This saves considerable wear on the mechanical brakes and returns energy to the supply system instead of dissipating it in the form of heat. It is, however, only in special cases that regenerative braking is economical.

LIGHTING AND HEATING.

The lighting circuit may be fed from :—

(1) Accumulators,
(2) The main power supply, up to 800 volts, or
(3) The low voltage auxiliary supply, when electro-pneumatic control is used.

The heating circuit is generally supplied direct from the line; electric boilers on

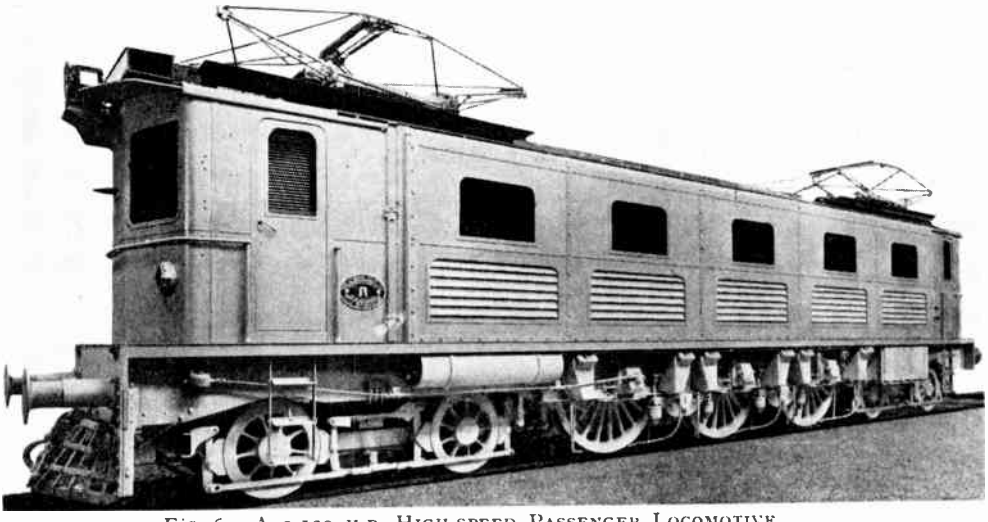


Fig. 6.—A 2,130 H.P. HIGH-SPEED PASSENGER LOCOMOTIVE.
The normal maximum running speed of this locomotive is 75 m.p.h. (*G.E.C.*)

the locomotive or radiators on the coaches are employed where necessary.

ADVANTAGES OF ELECTRIFIED RAILWAYS.

These may be summarised as follows :—

(1) No energy wasted in hauling power generating plant.

(2) Trains always ready for use to full capacity of motors.

(3) Trains in service nearly twenty-four hours a day, due to simple overhauling and maintenance.

(4) High acceleration (1-1½ m.p.h.p.s.—two or three times that of the average steam train) and hill-climbing powers due to the unlimited power supply and the steep torque-speed characteristic of the motors. Hence, higher average speed.

(5) Trains driven from either end, reducing shunting at terminals.

(6) Need for special driving skill eliminated by automatic acceleration.

(7) Reversible action of motors allows electrical braking, saving power and reducing wear on mechanical brakes.

(8) Elimination of smoke nuisance.

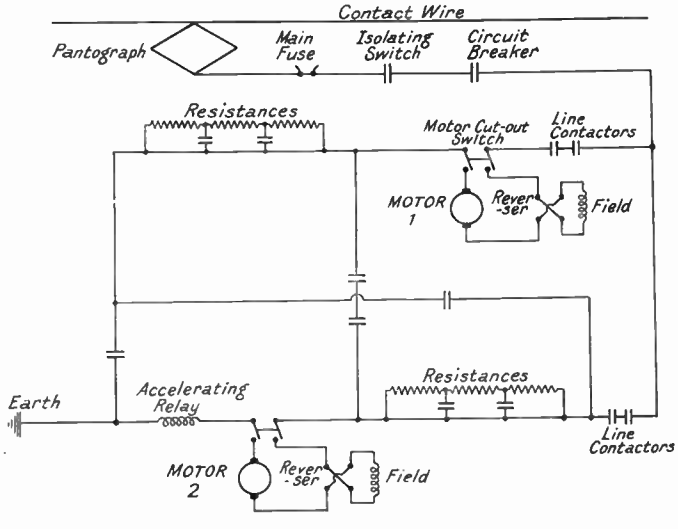


Fig. 7—SIMPLIFIED DIAGRAM OF POWER CIRCUIT
1,500 volts D.C., two motors, overhead collection, series-parallel operation.

HOW TO MAKE AN ELECTRIC KETTLE

By H. J. BALDWIN.

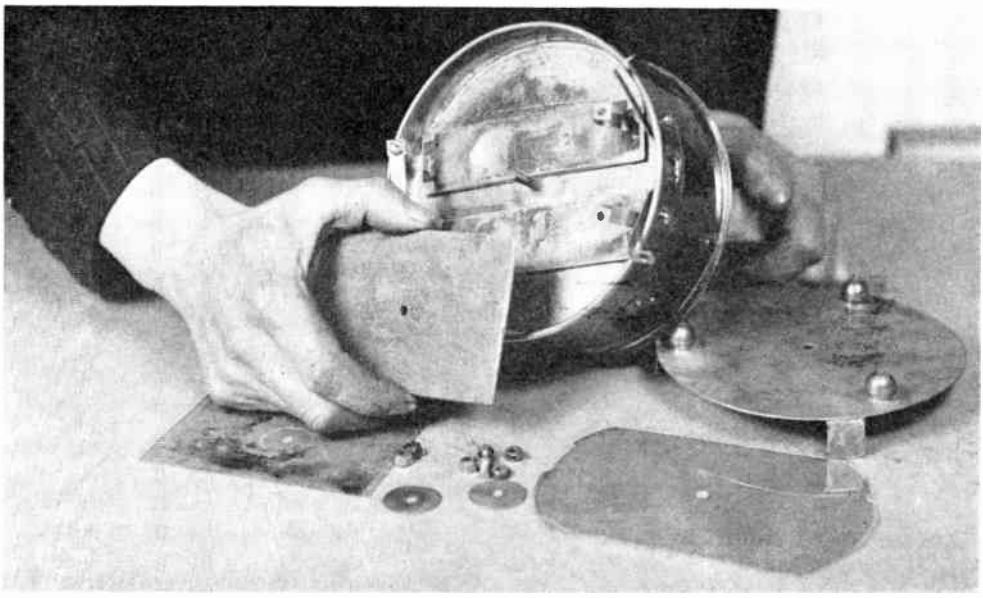


Fig. 1.—ASSEMBLING THE COMPONENTS OF THE ELECTRIC KETTLE.
This shows the heater elements fixed in position approximately $\frac{3}{8}$ of an inch from the central bolt. The thick brass cover plate (which is being held in the right hand) is placed in position with the concave side against the elements.

IN this article the reader is shown an easy and interesting method of converting an ordinary kettle into a useful and reliable electrical untensil. The idea can be equally well applied to any vessel used for boiling, such as a saucepan or coffee pot. The result will be an efficient, durable article, made at about one-third of the cost of the ready-made production.

Materials Required.

Select a two-pint copper kettle in which the sides and base are all in one piece, or difficulty may be experienced in fixing on the flange if the bottom is soldered to the sides. In addition, we shall need :—

A strip of copper, gauge 24-26, 20 inches by $1\frac{1}{2}$ inches, for the flange.

Piece of tinned iron wire, gauge 16, and 20 inches long, to wire the edge.

Sheet brass, gauge 22, 6 inches square, for the base.

Piece of brass or iron, 3 inches by $4\frac{1}{2}$ inches by $\frac{1}{8}$ inch, to clamp down the elements.

Two " Creda " elements of the correct voltage rated at 325 watts each.

Sheet mica, one piece $3\frac{1}{4}$ inches by $4\frac{3}{4}$ inches, and the other 3 inches by $5\frac{3}{4}$ inches.

Other items include $\frac{3}{16}$-inch bolt and three nuts, three brass balls $\frac{1}{2}$ inch diameter, two hollow sockets with external thread, strip of fibre 2 inches by $\frac{3}{4}$ inch, and few odd strips of gauge 22 brass.

This article on How to Make an Electric Kettle will be continued in Part 13. Ready January 8th.

George Newnes, Ltd.

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